Chapter 2

ACCOUNTING FOR HOUSING IN A CPI

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> "Construction of the U.S. CPI mirrors the national income accounts treatment of owner occupied housing. Owners are assumed to rent their homes from themselves, creating a category called Owner Equivalent Rent (OER). And because more than two-thirds of U.S. households own the house that they live in, OER's weight in the CPI is substantial; it accounts for 23.8% of the headline CPI and 30.8% of the traditional core CPI that excludes food and energy. Not surprisingly, how you measure something this important is a very big deal."
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> (Stephen Ceccheti, 13 June 2007, http://www.voxeu.org/index.php?q=node/248)

1. Introduction

Stephen Ceccheti, a former Executive Vice President and Director of Research at the U.S. Federal Reserve Bank of New York, argues in the lead quotation that the treatment of owner occupied housing (OOH) in a nation's CPI "is a very big deal." Judged by the household expenditure budget share of shelter for virtually every nation, Ceccheti is surely right. Yet, this is a measurement area where the development of harmonized official practices has been an elusive objective.[2] The differing treatments of OOH in national CPIs undermine efforts to understand the inflation and economic growth experiences of nations.

In section 2, we provide an overview of the four main approaches in current use for dealing with housing in a CPI: (1) the rental equivalence, (2) user cost, (3) acquisitions and (4) payments approaches.[3] A fifth approach originally proposed by Diewert (2006a) is also

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[2] Eiglsperger (2006) of the European Central Bank made the following observations: "The Harmonised Index of Consumer Prices (HICP) plays a prominent role in the monetary policy strategy of the European Central Bank (ECB).... A very important and difficult conceptual issue which has not been finally decided upon is the treatment of expenditure on housing by homeowners. While the HICP already covers the expenditure of tenants (mainly rents), most of the expenditure of owner-occupiers on housing (OOH)... are not included in the HICP at present. This can be traced back to the different practices of treating OOH in national consumer price indices (CPIs).... "

[3] We use the terminology of the 2004 International CPI Manual (ILO et al., 2004), followed as well in the reviews of international practice of Eiglsperger (2006) and Christensen, Dupont and Schreyer (2005).

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mentioned: the opportunity cost approach, which incorporates elements of both the rental equivalence and the user cost approaches. Three of these approaches -- the rental equivalence, user cost and opportunity cost approaches -- aim to price the use (i.e., the consumption) of housing services as this occurs, month by month, over time. These three approaches can be derived from the same theoretical foundations:[4] a model that has origins in the economics and accounting literatures on business investment.[5] Section 3 outlines these foundations, and the user cost is defined and related to depreciation and both general and asset class specific inflation rate parameters.

All dwellings are unique in some ways, including their locations.[6] Measurement challenges that arise with unique assets are discussed in section 4. In section 5, we suggest methods for dealing with complications due to the bundled land and structure components of residential properties.

Verbrugge (2006), Garner and Verbrugge (2008), and Gordon and Goethem (2004) raise some seemingly fundamental, and very different, concerns about the user cost and rental equivalence approaches. These concerns are considered in section 6.

For issues fraught with nation specific details where international agreement is needed, the way forward is often to focus on broad stroke differences among the various conceptual approaches in hopes that agreement on details will follow once the conceptual differences are clarified. However, the section 6 materials suggest that, for OOH, the way forward may involve looking more carefully at application specific details. Section 7 concludes.

2. Different Concepts of the Cost of Owner Occupied Housing (OOH)

We begin our overview of alternative approaches for dealing with OOH with the rental equivalence approach. Examples of the implementation of each approach are given, with the exception of the new opportunity cost approach.

2.1 The Rental Equivalence Approach

[4] Thus, Katz (2007) writes: "The "user cost of capital" measure is based on the fundamental equation of capital theory. This equation, which applies equally to both financial and non-financial assets, has been known since at least the middle of the 19th century. It states that in equilibrium, the price of an asset will equal the present discounted value of the future net income that is expected to be derived from owning it." The view that the appropriate value for an asset is the discounted stream of the expected future net revenue flow from the asset was actively advocated by Irving Fisher (1897, 1930). Böhm-Bawerk (1891, p. 342) was perhaps the first to notice this principle. There has also been some interest in the accounting literature in evaluating an asset value by the discounted stream of its future expected returns. For example, Mattessich (2005, p. 128) notes that: "During the second half of the century the influence of economics and the emergence of "finance" (as a subject independent of accounting) gave a decisive boost to the further exploration of the present value approach for accounting (including statement presentation)." See also Wagenhofer (2004) and Beidelman (1973).

[5] See Diewert (2003a) (2005a).

[6] Capozza, Israelsen and Thomson (2005) refer to the atypicality of a house that has acquired unusual features as it aged. Appraisers may have a difficult time finding comparable houses in the neighbourhood and may discount the appraisal value because of this.

The rental equivalence approach values the services yielded by the use of a dwelling by the corresponding market rental value for the same sort of dwelling for the same period of time (if such a rental value exists). Two nations that use this approach for their CPIs are the United States and Germany.[7] Our summary descriptions that follow of the CPI treatment of OOH in the United States and Germany necessarily include some material about renter occupied housing (ROH) as well. (Although the focus in the literature has been on the CPI treatment of OOH rather than ROH, there are issues deserving of attention for ROH as well, and what is done with ROH inevitably carries over into the treatment of OOH when the rental equivalence approach is used for OOH.)

2.1.1 The U.S. case[8]

The *shelter index* in the CPI for the United States is the expenditure weighted average of several component indexes. The Rent of Primary Residence Index (hereafter referred to as the *rent index)* and the Owners' Equivalent Rent of Primary Residence Index (hereafter referred to as the *rental equivalence index*) being the two main components of the CPI.

The CPI Housing Survey is the source of the data on residential rents used to compile the rent index. *Initiation* is the term the BLS uses to refer to the initial collection of rent data for a selected dwelling. After initiation, the rent for the dwelling unit is priced on a continuing basis while it remains in the panel. The initial rent is the basis for all calculations of rent change that occur during the life of a rental unit in the sample.

The BLS compiles data on the monthly economic rent for each renter occupied dwelling included in the CPI Housing Survey. The *economic rent* for a dwelling is the contract rent (including the value of certain rent reductions) adjusted by the value of any changes in the services the landlord provides. The BLS also derives data on the monthly *pure rent* for use in OOH rental equivalence computations. For compatibility with the expenditures owner occupiers face, pure rents exclude the cost of any utilities included in rental contracts.

Expenditure weights are used for combining the economic rent data and the pure rent data (all collected from renters in the CPI Housing Survey) into the rent index and the rental equivalent index components of the CPI shelter index.[9] The expenditure data are from

[7] Rental equivalence is also the approach taken in the *System of National Accounts: 1993* (Eurostat et al. 1993, p. 134) for owner occupied housing. Eurostat's (2001, p. 99) *Handbook on Price and Volume Measures in National Accounts* also recommends the rental equivalence approach for the treatment of the dwelling services for owner occupied housing. To implement the rental equivalence approach, the relevant rental or leasing markets exist.

[8] This section draws on the U.S. Bureau of Labor Statistics (BLS) (2007).

[9] When an owner occupied housing component was first introduced into the CPI of the United States, the rental equivalence index was calculated by reweighting the rent sample to represent owner occupied units. Then owing to concerns that the mix of types of rental units and also where they are located are different from OOH, from 1987-1998, the BLS tried other methods for implementing a rental equivalence approach for owner occupied housing. However, in January 1999, the agency returned to the method used for the rental equivalence index when it was first introduced. See also Crone, L.I. Nakamura and Voith (2000, 2008) and Heston and Nakamura (2008) for more on the BLS methods, and the associated methods used by the U.S. Bureau of Economic Analysis (BEA) for the treatment of owner occupied housing in the national accounts for the United States.

households in the Consumer Expenditure (CE) Interview Survey. Both renters and homeowners are included in the CE sample. For renters, the expenditure weight information is obtained by asking sampled census unit (CU) renter households the following question:

> "What is the rental charge to your CU for this unit including any extra charges for garage & parking facilities? Do not include direct payments by local, state or federal agencies. What period of time does this cover?"

For owner occupiers, the expenditure weight information is obtained by asking sampled owner households the following question:

> "If someone were to rent your home today, how much do you think it would rent for monthly, unfurnished and without utilities?"

BLS then uses the *economic rents* and the *renter expenditure weights* to estimate the changes for the *rent index*. Finally, the BLS uses the *pure rents* and the corresponding *owner expenditure weights* to estimate the change for the OOH *rental equivalence index*.

For reasons noted in section 6, it is easier to implement rental equivalence in the United States than in most other nations. In some respects, therefore, the U.S. implementation of rental equivalence can appropriately be viewed as both a best practice example, and the best attainable application, of the rental equivalence approach.

2.1.2 The German case

Kurz and Hoffmann (2004) report that in the German Consumer Price Index (CPI), as in the CPI for the United States, rents are used for the imputation of the costs of owner occupied housing, which is achieved by altering the expenditure weights for the rental data. Approximating OOH costs by means of the rent index is said to be valid for Germany because the German housing market is lightly regulated, the tax system is not severely distorting, and the share of rental housing is quite substantial.

However, the structure of owner occupied housing differs substantially from that of rental housing. Rental housing typically takes the form of flats in apartment houses, whereas single family houses and terraced houses predominate in the owner occupied segment. Furthermore, only rents for a restricted sample of dwellings are recorded for the CPI purposes. The potential consequences of these rental housing versus owner occupied housing mix differences are examined by Kurz and Hoffmann (2008).

2.2 The User Cost Approach

The user cost for owner occupied housing can be theoretically derived, and could potentially be computed, as the costs borne by a household for purchasing a home at the beginning of the unit time period, living in it during the period, and re-selling it at the end of the period. Mortgage interest payments, maintenance and repair, insurance premiums, and taxes are typical recurring cost items for homeowners of living in their own dwellings: what we will refer to sometimes as *housekeeping costs*. The *full ex ante user cost* consists of the *housekeeping costs* plus anticipated normal physical *depreciation*, plus the *waiting costs* (the costs of forgone interest due to the funds tied up in the owned dwelling) and *anticipated capital gains* (or losses) due to housing market specific inflation over the given time period. The *full ex post user cost* has the same components as the corresponding ex ante user cost except that ex post or actual capital gains or losses are used in place of anticipated gains or losses.

In times when housing prices are rising steeply, ex post user costs can be negative. If we want the user cost to approximate a market rent, the ex ante concept must be used: landlords who have an ex post negative user cost will generally not rent their properties at a negative price! The issue of negative user costs is addressed in subsequent sections.

Official statistics institutes that have adopted user cost approaches have generally *not* adopted the full user cost approach; they have adopted various modified user cost approaches. We review the Canadian and Icelandic cases below.

2.2.1 The Canadian case[10]

For owner occupied accommodation, Statistics Canada produces a *modified user cost* measure that includes six elements of homeowner expense:

a) Mortgage interest cost;

b) The cost of regular ongoing maintenance and repairs and other owned accommodation upkeep expenses;

c) The cost of homeowners' insurance;

d) Property taxes; and

e) Replacement cost (i.e., depreciation).

Note, however, that the Statistics Canada CPI treatment of OOH *omits the waiting cost items of the full user cost*: foregone interest on funds tied up in an owned dwelling and capital appreciation or depreciation. In fact, if the depreciation term were dropped from the Canadian treatment, the resulting price of housing services would be a variant of the *payments approach* to OOH, discussed below.

2.2.2 The Icelandic case[11]

The rental rates reported by tenants (about 18% of households, based on Statistics Iceland's consumer survey) form the basis for a rent component in the Icelandic CPI.

The shelter index for the Icelandic CPI has two main components. The first is a housekeeping type expenditures index that takes into account minor maintenance as well as

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[10] The information in this section is mostly from Statistics Canada (2007) and Statistics Canada (1995). For more on the treatment of OOH in the Canadian CPI, see also Baldwin, A. Nakamura and Prud'homme (2008) in this volume.

[11] Material in this section is based on Guðnason (2005a, 2005b), as well as Guðnason and Jónsdóttir (2008) in this volume. Private communications with Rósmundur Guðnason of Statistics Iceland and Jón Steinsson, now with Columbia University but formerly with the Bank of Iceland, have also been of great help on understanding the specifics of the Icelandic user cost calculations.

charges for sewerage, refuse collection and water supplies.[12] The other component is an "owner equivalent rent," referred to by Statistics Iceland as a simplified user cost.[13] What follows is a brief explanation of Iceland's owner equivalent rent component. For further details on the Icelandic approach, see Guðnason (2005a, 2005b) and Guðnason and Jónsdóttir (2008).

Copies of all sales deeds for residential housing must be filed with the Land Registry. The deeds state the purchase price of the property together with the provisions for buyer liabilities. These liabilities take four forms:

1. The buyer makes a cash payment on signing the deed of sale. If the buyer has taken a loan from a pension fund or a bank for the cash down payment, it is classified here. So are supplementary loans from the Icelandic Housing Financing Fund (the HFF), which are paid out in cash.

2. The buyer commits to make payments.

3. The buyer transfers bonds to the seller: generally swappable housing bonds. When the buyer takes a loan from the HFF, the HFF issues the seller housing bonds in return.

4. The buyer assumes the seller's financial obligations in connection with the property.

The Land Registry of Iceland determines the present value of each registered property.

According to the deed of sale, the purchase price is equivalent to the total nominal value of payments according to items 1 and 2 above, the nominal value of the housing bonds received by the seller under item 3, and the total current value of the principal of the financial obligations taken over by the buyer according to item 4. For a realistic picture of the cost of owner occupied housing, it is not enough to consider merely the buying price. The cost also depends on the scheduling of payments under item 2, the discount on housing bonds paid according to item 3, and the interest terms for the buyer obligations under item 4. The Land Registry evaluates all these payments, according to the details in the deed of sale, and computes the present discounted value for the sale.[14]

Owner equivalent rent is intended to reflect changes in market prices of housing and also financing costs and depreciation.

The Land Registry calculates the cash price per square metre for several categories of residential housing and multiple regions. More specifically, deeds of sale are classified according to whether the housing is in the Greater Reykjavík Area or in other regions, and whether it is detached or multi residential (i.e., an apartment). Each category is divided into four subcategories by size. The average price per square metre is calculated for each subcategory. Statistics Iceland uses the Land Registry's data for average price per square metre in its calculations of owner equivalent rent. Three-month averages are used. Thus the housing price in the Greater Reykjavík Area that is used for calculating the May CPI is the average price of

[12] This housekeeping component was about 3.6% of total expenditure in the CPI base for March 2002.

[13] This component amounted to about 10.1% of total expenditure in the CPI base for March 2002.

[14] Since payments under item 1 are made in cash, they do not need to be revalued at present discounted value. The Land Registry uses overdraft interest rates to calculate the present discounted value of payments according to item 2. The Land Registry uses the market yield on housing bonds plus a premium of 0.35% when it calculates the present discounted value of payments according to items 3 and 4. See Ingvarsson (2002, p. 260).

housing sold in the period of January to March. Statistics Iceland weights the average price in each category by the number of transactions in that category over a three-year period.

The interest cost on owner occupied housing is a share weighted average of the interest calculated in two ways: using real rates of interest on collateral loans, and 3 percent real interest on the part of the value of the housing which is classified as owner's equity. Thus, for the latter interest component, the interest rate is not allowed to change, but the interest rate for the first component does change in line with the terms of the loans specified in the housing sale agreements. Recently, owners' equity has accounted for just over half the value of housing, and average real interest rates have been just over 5 percent.[15]

Statistics Iceland assumes that housing structures have a lifetime of 67 years (with a depreciation rate of 1.5 percent per year) and with the real value of the plot of land treated as remaining unchanged. For the sake of simplification, the combined value of the housing and plot of land are treated like an asset with a lifetime of 80 years (depreciated by 1.25 percent per year). Thus N equals 80 in the user cost formula used by Statistics Iceland, and the user cost for a property is computed as the product of the present value of the property sale times the term $r/[1-(1+r)^{-N}]$ where r is the real interest rate (determined each period as explained above).

2.3 The Acquisitions Approach

The acquisitions approach can be applied to OOH, just as it is to all other goods and services covered by a CPI. The objective is to measure the average change in prices of the goods and services acquired by households each period, irrespective of whether they were wholly or even partially paid for (e.g., purchases on credit), and irrespective of whether the purchased assets were used, that period.

For the acquisitions approach, only goods that the household sector purchases from *other* sectors of the economy are in scope. For any property that is fully in scope because ownership was acquired in the given time period and it was purchased from *outside* the household sector (e.g., properties being sold by a development company), the full sales price is counted in the period of the sale. Also, the net acquisitions approach includes in-period costs of services relating to the buying and selling of second hand houses such as real estate agent fees and asset transfer taxes.

For most sorts of goods in industrialized nations, the direct sales by households to other households are a very small proportion of total sales.[16] Thus, limiting the CPI coverage to

[15] In Iceland, at present, a large part of housing loans are at rates which are not determined directly in the market. This applies, for example, to loans from the Housing Financing Fund (HFF) and some pension fund lending to homebuyers. Under these conditions, a general rise in the real interest rate has relatively little impact on the interest rates used to calculate owner equivalent rent. On the other hand, a general increase in interest rates which raises the yield on housing bonds can lower the cash price of the housing by reducing the present discounted value of loans bearing fixed real interest. Head on competition between the banks and the HFF has been viewed as a problem by the government.

[16] This is still the case even if household-to-household sales facilitated by intermediaries such as consignment companies and match making services such as E-Bay are treated as household-to-household.

purchases from other sectors makes little difference for most goods and services. However, when the acquisitions approach is used for OOH, what enters the CPI for housing are mostly expenditures on new dwellings excluding land, with almost all second hand dwellings and even most of the land used for new home construction being excluded due to prior ownership within the household sector. For example, if the land on which a new house sits was previously owned by another household, then the cost of this land is excluded from an acquisitions type house price index even though the house structure is new and is counted.

The acquisitions approach is used by Australia and New Zealand. This is also the approach that has been tentatively settled on for the European Union's Harmonized Indices of Consumer Prices (HICPs).[17]

2.3.1 The New Zealand case

The New Zealand CPI (like the Australian CPI) is compiled using an acquisitions framework. The expenditure weight allocated to the purchase of housing represents the value of the net increase in the stock of owner occupied housing during the weight reference period. Expenditure on newly constructed dwellings by owner occupiers is included, as are alterations and additions to established owner occupied dwellings. Sales within the household sector of established owner occupied dwellings are viewed as not adding to the stock and are not counted.

2.4 The Payments Approach

The payments approach only measures actual cash outflows associated with owning and occupying a home. Thus the consumption of OOH services gets little or no weight for dwellings already fully paid for.

2.4.1 The Irish case

The Central Statistics Office of Ireland (2003) uses the payments approach for OOH in their CPI. For owner occupiers, the Irish CPI covers the following cost items:

a) Mortgage interest,

b) Repairs and decorations, and house maintenance services;

c) House (dwelling and contents) insurance; and

d) Local authority charges.

Mortgage interest payments are measured using a fixed basket profile of mortgages up to twenty years in duration. Mortgage capital repayments and down payments on dwelling purchases are not covered in the CPI as they are considered to be investment.

[17] The HICPs are the official measure of consumer price inflation for the purposes of monetary policy in the euro area and for assessing inflation convergence as required under the Maastricht criteria. See the European Communities (2004).

2.5 Diewert's Opportunity Cost Approach

The *opportunity cost approach* to the treatment of OOH is too new to have been implemented by any statistical agency. Diewert (2006a, p. 27) explains this approach as follows:

> "[P]erhaps 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, which is the financial opportunity cost of housing, 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."

The home owner's internal user cost is the *financial opportunity cost of owning the dwelling unit*; i.e., it focuses on the financial capital that is tied up when one owns the home. This is the user cost concept discussed in the following section. Diewert, in the above quotation, notes that the home owner faces another opportunity cost; namely the rent that the homeowner could receive if the dwelling unit was rented out to a tenant. Thus *the effective opportunity cost of OOH* is not the financial user cost *or* the rental opportunity costs but the *maximum* of these two. Diewert goes on to observe that: "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." The empirical results obtained by Heston and Nakamura (2008) and their suggested explanations for these results raise the possibility also that, for some groups of homeowners, the financial opportunity cost may systematically dominate the rental opportunity cost of OOH, and vice versa.

Note that the opportunity cost approach to OOH resolves potential problems associated with negative ex post or ex ante user costs. The opportunity cost price for OOH can never be negative.

3. The Theory of Household User Costs

Diewert (1974, p. 504) sets out the user cost principles for consumer durables:

> "To form the rental price (or user cost) for the services of one unit of the nth good during period t, we imagine that the consumer purchases the good during period t and then sells it during the following period (possibly to himself). Then the discounted expected rental price for the nth consumer good during period t is given by the discounted cost of the purchase of the nth good during period t minus the discounted resale value of the depreciated good during period t + 1."

The "resale value of the depreciated good during period $t+1$," referred to in the above quotation from Diewert (1974), includes the loss in potential resale value due to physical depreciation and any anticipated or expected holding gains or losses for that type of asset. This user cost approach is what price statisticians refer to as the full user cost approach.[18]

Unfortunately, there is often a large divergence between user costs and the corresponding market rents. This can be seen, for example, from table 4 in Heston and Nakamura (2008) which shows that as dwelling units become more valuable, the ratio of the estimated market rental price to the asset value of the unit drops rather steeply to about one half of the initial ratio.[19] The rent to value ratio should be approximately equal to the sum of the housing depreciation rate plus the property tax rate plus the nominal opportunity cost of capital less the anticipated rate of property price inflation. All of these rates should be approximately constant as the value of the property increases.[20] *The evidence presented by Heston and Nakamura (2008) suggests that the rental equivalence approach to OOH will give a substantially lower share to OOH in a CPI compared to a user cost approach or to an opportunity cost approach.* Diewert (2002, p. 619) noted that expenditure weights using the user cost approach to OOH were likely to be considerably higher than the corresponding weights obtained using the acquisitions (also sometimes called the money outlays) approach. If the empirical results of Heston and Nakamura (2008) are applicable to other countries, then user cost expenditures are likely to exceed the corresponding rental equivalence expenditures which in turn are likely to be greater than acquisitions expenditures. Thus, alternative treatments of OOH are likely to give rise to different movements in the CPI.

Girouard, Kennedy, van den Noord and André (2006) also present evidence that the ratio of market rents to the underlying asset value of the dwelling unit varies substantially over time. This empirical evidence, along with that presented by Heston and Nakamura (2008), suggests that the substantial transactions costs associated with a change in housing status can contribute to a divergence of the usual financial user costs from the corresponding market rents. The issues surrounding the choice of approach to OOH to take for a CPI are discussed further in section 6. The rest of this section is devoted to the traditional financial user cost approach.

In box 1, the derivations are shown for alternative expressions for the full user cost for a dwelling, measured as of the beginning of period 0.[21] The time period is indicated by the superscript t and the number of periods a dwelling has been used as of the beginning of the designated time period is denoted by the subscript v. Thus, p_0^0 is the price of a new dwelling at the beginning of period 0, and p_1^1 is the price of a dwelling used for one period as of the start of period 1. The expressions in box 1 abstract from housekeeping expenses.

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[18] Diewert (1974, 1980; pp. 470-486, 2003a) followed Fisher (1897; p. 527) and Hicks (1939; 122) and derived his user costs using a discrete time approach as opposed to the continuous time approaches used by Jorgenson (1963, 1967), Griliches (1963), Jorgenson and Griliches (1967, 1972) and Christensen and Jorgenson (1969, 1973). For more recent research on user costs and capital measurement, see Hulten and Wykoff (1981a, 1981b, 1996), T.P. Hill (1999, 2000, 2005), Diewert and Lawrence (2000), R.J. Hill and T.P. Hill (2003), Corrado, Hulten and Sichel (2005), Diewert (2005a, 2005c) and Diewert and Wykoff (2008).

[19] For example, in the Washington D.C. area, the rent to value ratio is in the 8.8 to 8.9 percent range for a $50,000 unit which drops to 4.2 to 4.3 percent for a $500,000 unit.

[20] One could make the case that more expensive properties have a higher land component and thus the overall depreciation rate for the dwelling unit and the land associated with it should be higher for the less expensive properties. On the other hand, properties with more land generally have more expensive structures built on them.

[21] We are abstracting in this section from housekeeping expenses incurred by living in the dwelling, as well as from issues of renovation and land/structure/equipment dwelling composition complications: issues taken up in section 6.

Box 1. Beginning of Period User Costs Evaluated Ex Post

As in Diewert (2003a) and abstracting here from direct operating homeowner costs for expositional simplicity, let p_v^t denote the price paid for a dwelling that is v periods old at the beginning of period t. To determine the net cost of using the dwelling during period 0, we begin with the purchase price at the beginning of the period: p_0^0. Suppose the dwelling can be sold at the end of period 0 (which we take to be the same point in time as the beginning of period 1) at the price of p_1^1.

If there is positive inflation, money is less valuable when received at the end versus the beginning of a period. For period t, the end of period value can be converted to its equivalent at the beginning of that same (*not* the next) period by discounting by the term $1+r^t$ where r^t is the beginning of period t nominal interest rate.

Let u_v^t denote the one period *user cost, as of the beginning of period t,* for using a dwelling that is v periods old; that is, this is the price of using the a dwelling for the period t time interval. The period 0 user cost for the new dwelling is defined, using price data for this same dwelling from the beginnings of periods 0 and 1, as:

(2-1) $$u_0^0 \equiv p_0^0 - p_1^1/(1+r^0)\,.$$

The second term in (2-1) is the price for the one period old dwelling discounted to the beginning of period 0.

Suppose the consumer purchases the new dwelling at the beginning of period 0 at the price p_0^0, charges the self imposed rental price of u_0^0, and views the remainder of the purchase price as an *investment*:

(2-2) $$I^0 \equiv p_0^0 - u_0^0\,.$$

The rate of return that could potentially be realized on the investment defined by (2-2) is the interest rate r^0 that the consumer faces at the start of period 0. Financial capital theory implies that p_1^1, the selling price that could be realized for the dwelling at the end of period 0, should satisfy the following equation:

(2-3) $$I^0(1+r^0) = p_1^1\,.$$

The user cost formula (2-1) can be put into a more familiar form using the economic depreciation and housing specific inflation rates. The *depreciation rate for a new dwelling* (i.e., a dwelling with v=0) over one time period, denoted by δ_0, reflects the loss of economic value with normal use and maintenance, and is defined by:

(2-4) $$(1-\delta_0) \equiv p_1^1/p_0^1\,.$$

The *housing specific inflation rate for a new dwelling over period 0* is denoted by i^0 and is defined by:

(2-5) $$1+i^0 \equiv p_0^1/p_0^0\,.$$

Thus the *depreciation rate* is defined by the ratio of the same period prices for dwellings that have been used for different lengths of time whereas the *inflation rate* is defined by the ratio of the prices at different points in time for items used the same length of time.

Eliminating p_0^1 from (2-4) and (2-5) leads to the following expression for the end of period 0 used dwelling price as a function of the cost at the beginning of period 0:

(2-6) $$p_1^1 = (1-\delta_0)(1+i^0)p_0^0\,.$$

Substituting (2-6) into (2-1) yields another expression for the beginning of period 0 user cost of a new dwelling:

(2-7) $$\begin{aligned} u_0^0 &= [(1+r^0) - (1-\delta_0)(1+i^0)]p_0^0/(1+r^0) \\ &= [(r^0 - i^0) + \delta_0(1+i^0)]p_0^0/(1+r^0) \\ &= (r^{0*} + \delta_0^*)p_0^0/(1+r^0). \end{aligned}$$

where $r^{0*} = r^0 - i^0$ is a period 0 *real interest rate* and $\delta_0^* = \delta_0(1+i^0)$ is an *inflation adjusted depreciation rate*.

Suppose, for the moment, we also ignore inflation; hence $r^t = 0$ in box 1 for $t = 0,1$.[22] Without inflation, we see from (2-1) that the user cost is defined simply as the purchase price of the new dwelling minus its resale price one period later. From (2-6) in box 1, we see that the resale price equals the original purchase price times two terms. The first of the terms on the right hand side of (2-6) reflects the one period loss in dwelling value due to physical depreciation. This term is defined in (2-4) as the ratio of the resale price of the dwelling at the end of period 0 (which is the beginning of period 1), and the price at the end of period 0 of a hypothetical comparable home that is new then. The second term on the right hand side of (2-6) is a housing specific inflation rate, which can be measured (as in (2-5)) as the ratio of the price at the end of period 0 of a hypothetical comparable new home to the new price at the beginning of period 0 for the given home. Expressions like (2-6) in box 1 have been presented in the accounting literature going back, at least, to the early 1900s when Daines (1929) and Sweeney (1934) wrote. (For more on this topic, see appendix A and also Diewert 2005a, chapters 2, 3 and 7.)

Attention to timing matters for understanding the alternative ways in which user costs can be defined. Realized prices are determined at points in time. Rates of interest are also regarded as fixed at points in time. In contrast, rates of inflation are defined for time intervals. In box 1, the user cost is expressed in terms of prices discounted to the *beginning* of period 0. The conventions used in financial accounting suggest that flow transactions within an accounting period should be regarded as taking place at the end of the period. This would suggest that an end of period, rather than a beginning of period, user cost should be used. The user cost can be mechanically recast in an end of period format by "reverse discounting." (See the top section of box 2.)

There is no way of knowing an actual inflation rate until the end of the period for which it is defined. However, this rate could be estimated and anticipated, as those deciding on the purchase of assets like owned housing must do in real life. In the bottom portion of box 2, beginning of the period user costs are defined using an anticipated inflation rate. The Statistics Iceland simplified user cost method for including OOH services costs in their CPI (see section 2.2.2) makes use of equation (2-9) in box 2.[23] This method requires some way of determining:

- The current period sale prices for homes,
- The anticipated real interest rate ($r^{0*} = r^0 - i^0$),
- The home depreciation rate,
- The rate of value loss due to the physical depreciation of homes, and
- The value of the housing stock.

[22] The equations in Diewert's (2003a) paper are formulated for the illusory case of a household durable bought new in period 0 and used for one period (i.e., used to the end of period 0 which is the beginning of period 1. For many consumer durables, from clothes to couches, most of the items purchased by households *are* new. However, this is less the case for cars, and mostly not the case for dwellings. Price developments over the first few years following a change of ownership are not the same for homes purchased new as for homes already a few years old at the time of the most recent change of ownership. This is why nations like Canada have a separate price index for new home sales. In actual application, any two periods could be substituted for periods 0 and 1 in box 1, and v (which denotes the dwelling age at the beginning of the first period) could take on other values too.

[23] See the remarks following equation (9) on pages 12-13, and also (54) and (55) on pages 28-29 in Diewert (2003a).

Box 2. Other Ways of Defining User Costs

End of Period User Costs

For a new dwelling at the end of period 0, we can define an end of period user cost equivalent to the beginning of period user cost given in (2-7) in box 1, which Diewert (2003a) terms "an *approximate rental* cost", as:

$$
\begin{aligned}
\varphi_0^0 &\equiv (1+r^0)u_0^0 \\
(2\text{-}8) \qquad &= [(r^0 - i^0) + \delta_0(1+i^0)]p_0^0 \\
&= (r^{0*} + \delta_0^*)p_0^0 .
\end{aligned}
$$

If the real interest rate r^{0*} is defined as the nominal interest rate, r^0, less the dwelling inflation rate, i^0, and the small term, $\delta_0 i^0$, is ignored, then the end of period user cost given by (2-8) reduces to:

(2-9) $$\varphi_0^0 \cong (r^{0*} + \delta_0)p_0^0 .$$

Thus the user cost (whether beginning or end of period) is determined primarily by the (real) opportunity cost of the capital tied up, given by $r^{0*}p_0^0$, plus the decline in value of the dwelling over the period due to depreciation.

Beginning of Period Anticipated User Costs

Diewert (2003a) suggests that the actual asset inflation rate, i^t, in (2-5)-(2-7) can be replaced by an estimated or anticipated housing inflation rate, denoted by i^{ta}. Thus, (2-7) becomes:

$$
\begin{aligned}
(2\text{-}10) \qquad u_0^0 &= [(r^0 - i^{0a}) + \delta_0(1+i^{0a})]p_0^0 /(1+r^0) \\
&= (r^{0*a} + \delta_0^{*a})p_0^0 /(1+r^0).
\end{aligned}
$$

The term $r^{0*a} = (r^0 - i^{0a})$ can now be loosely interpreted as a housing specific *anticipated* real rate of interest. Also, the inflation adjusted depreciation rate must be replaced by an *anticipated* inflation adjusted rate: $\delta_0^{*a} = \delta_0(1+i^{0a})$.

Statistics Iceland incorporates an asset specific inflation rate into their user cost calculation, with this being multiplied by the property value figure, thereby reflecting residential property appreciation. Depreciation is allowed for, but the treatment is largely by assumption. The same rate is applied, period after period. The rationale for this approach has been widely used for reasons articulated more than 100 years ago by Ewing Matheson (1910/1884, p. 35):

> "The plan of valuing every year instead of adopting a depreciation rate, though it might appear the more perfect, is too tedious and expensive to be adopted ... the next best plan, which is that generally followed ... is to establish average rates which can without much trouble be written off every year, to check the result by complete or partial valuation at longer intervals, and to adjust the depreciation rate if required."

Many others have held similar views. For instance, Daniels (1933) writes:

> "The function of depreciation is recognized by most accountants as the provision of a means for spreading equitably the cost of comparatively long lived assets. Thus, if a building will be of use during twenty years of operations, its cost should be recognized as operating expense, not of the first year, nor the last, but of all twenty years....The important matter is that at the time of abandonment the cost of the asset shall as nearly as possible have been charged off as expense...."

Box 3. Depreciation for Durables with Long Service Lives

Let δ_v be the depreciation rate for a dwelling that is v periods old at the beginning of the given period. Depreciation rates can be defined recursively, starting with the rate for a brand new dwelling. Following Diewert (2003a), and applying the same definition as is used for period 0 and 1 prices in (2-4), δ_0 is defined here by $(1-\delta_0)\equiv p_1^0/p_0^0$, so $(1-\delta_1)(1-\delta_0)\equiv p_2^0/p_0^0$, where p_2^0, the beginning of period price for a unit of a dwelling that is 2 periods old, is compared to the price of a brand new dwelling at the beginning of period 0. Similarly, if we have values for the cross sectional depreciation rates for dwellings that are $0,1,2,\ldots,v-1$ periods old (i.e., if we know the values of δ_0, δ_1, $\delta_2,\ldots,$ δ_{v-1}), then the period 0 cross sectional depreciation rate for a unit of dwelling that is v periods old at the beginning of period 0, δ_v, is defined by:

(2-11) $$(1-\delta_v)\ldots(1-\delta_1)(1-\delta_0)\equiv p_{v+1}^0/p_0^0 .$$

Note that here, as is customary in the depreciation literature, the sequence of vintage depreciation rates is independent of the period t, so $\delta_v^t=\delta_v$ for all t and v. Thus a sequence of vintage (i.e., of used) dwelling prices at a point in time can be used to estimate the sequence of depreciation rates that apply for all time periods.

Recall the user cost formula for a new unit of a dwelling given by (2-1). The same approach leads to the following *beginning of period 0 sequence of vintage user costs*:

(2-12) $$u_v^0=\begin{cases}(1-\delta_{v-1})(1-\delta_{v-2})\ldots(1-\delta_{v-1})[(r^0-i^0)+\delta_v(1+i^0)]p_0^0/(1+r^0) & \text{for } v=1,2,\ldots\\ [(r^0-i^0)+\delta_0(1+i^0)]p_0^0/(1+r^0) & \text{for } v=0\end{cases}$$

When v = 0, define $\delta_{-1}\equiv 1$; i.e., the terms in front of the square brackets on the right side of (17) are set equal to 1. Note that if v = 0, then (2-12) reduces to (2-7).

In this case, all the cross sectional vintage depreciation rates in (2-12) are assumed to be equal to the same rate δ, where δ is a positive number less than one; i.e., for all time periods t and all vintages v, it is assumed that

(2-13) $$\delta_v=\delta .$$

Substitution of (2-13) into (2-12) yields the following for the sequence v = 0,1,2,… of *period 0 vintage user costs*:

(2-14) $$u_v^0=(1-\delta)^v[(r^0-i^0)+\delta_v(1+i^0)]p_0^0/(1+r^0) .$$

From (2-14) we see that, *given geometric depreciation, all of the vintage user costs are proportional to the user cost for a new dwelling*. Note that this proportionality means it is not necessary to use an index number formula to aggregate over vintages when forming a dwelling services aggregate.

If the anticipated interest rate is substituted for an actual one, this defines an anticipated sequence of user costs as of the beginning of period 0.

One way of attempting to determine a sequence of depreciation rates for a durable capital input as it ages was suggested by Böhm-Bawerk (1891): estimate the expected number of accounting periods n that the input is likely to be used in production and assume that the single period depreciation rate is $\delta=1/n$. This straight line method of depreciation can be used to allocate the initial purchase cost of the asset across the n periods of its life.

Another commonly used method for the determination of depreciation rates rests on the assumption that depreciation occurs on the undepreciated value of the asset at a *constant geometric rate* δ where $0<\delta<1$. This method, sometimes called the *reducing balance method* or the *declining balance method* in the accounting literature, is very convenient to apply. Yet, Canning (1929, pp. 265-266) cautions that: "Obviously the number of periods of contemplated use of an asset can seldom be intelligently estimated without reference to the anticipated conditions of use. If the formula is to be respectable at all, the value of n must be the most probable number of periods that will yield the most economical use."

The accounting profession primarily works for businesses. Historically, businesses self produced or bought most of their machinery and equipment new and then used it until it was ready to be scrapped. In that context, it may often make sense to represent depreciation, and also the user cost of capital, using only the price for the asset when new and the planned on number of periods until the asset will be scraped. In these situations, it may also make sense to focus on a user cost formulation that only contains price information for the durable good before it is used for the designated length of time, as in (2-7) in box 1.

The user cost expressions in boxes 1 and 2 are shown, for expositional convenience, in a two time period context. The formulas presented involve a depreciation parameter: δ. Box 3 shows assumptions under which a sequence of depreciation rates for houses built at different points in time -- i.e., for houses of different vintages -- can be summarized in terms of a single depreciation parameter.[24]

However, for houses, when there is active resale, it seems desirable to use this information to empirically determine the depreciation rate (or rates). The resale housing market is far larger and wider in its coverage of the range of different types of dwellings than are the resale markets for most sorts of business machinery and equipment.

4. Dealing with the Unique Aspects of Dwellings

The depreciation pattern for a durable can be determined empirically when there are multiple resale, or rental price, observations for dwellings that have been *used for different numbers of periods* between the points in time when price information was collected. Large numbers of dwellings of different vintages are sold each year in even a nation as small as Iceland.

Of course, all dwellings are unique in some respects, including their exact locations. If dwellings are regarded as unique for price measurement purposes, it will not be possible to empirically sort out the separate effects of depreciation and asset inflation: this is what Diewert (2003a) terms *a fundamental identification problem.*[25] Moreover, if the depreciation rate is determined by assumption or simplistic proxies, this *imposes* an allocation between dwelling deterioration and housing inflation effects. However, the prospects for learning from empirical observation improve greatly if dwellings can be viewed as the same provided they have certain shared characteristics. This is the basis of the repeat sales and hedonic approaches.

[24] For more on depreciation and some worked examples, see Diewert and Lawrence (2000) and Diewert (2003c). Additional examples and discussion can be found in OECD (2001a, 2001b).

[25] Special cases of this fundamental identification problem have been noted in the context of various econometric housing models: “For some purposes one might want to adjust the price index for depreciation. Unfortunately, a depreciation adjustment cannot be readily estimated along with the price index using our regression method.… In applying our method, therefore, additional information would be needed in order to adjust the price index for depreciation,” Bailey, Muth and Nourse (1963, p. 936). “The price index and depreciation are perfectly collinear, so if one cares about the price index, it is necessary to use external information on the geometric depreciation rate of houses,” Palmquist (2003, p. 43).

4.1 The Repeat Sales and Characteristics Period Dummy (CPD) Methods

Consider a dwelling which is new at the start of period 0 with price p_0^0. From (2-6) in box 1, the price, p_1^1, that this dwelling could be sold for at the beginning of period 1, when it has been used for 1 period, is:

$$p_1^1 = (1-\delta_0)(1+i^0)p_0^0 .$$

Thus the potentially observable period 1 used asset price p_1^1 is equal to the period 0 price of the new home, p_0^0, times the product of two factors: $(1-\delta_0)$, *a quality adjustment factor* that takes into account the effects of aging on the dwelling, and $(1+i^0)$, a period to period *pure price change factor* holding quality constant. The problem with unique assets is that cross sectional information on used asset prices at any one point in time will not allow us to separate out the effects of these two factors. However, this separation can be based on empirical evidence if some way can be found for deciding when different dwellings, that have been used different numbers of periods, can be viewed as comparable for depreciation measurement purposes.

The repeat sales method compares the price observations for housing properties that trade more than once over a given time interval.[26] Transaction data can be linked, so that we can compare the sales price for the same house at different times. The difference in those sales prices is an estimate of how much prices have increased for a particular bundle of attributes. We do not need to know the attributes to determine how much the price has changed. By taking the average increase in prices, the repeat-sales house price index can determine average house price appreciation rates without having to measure all the attribute characteristics of the properties sold. The underlying assumption is that, with normal wear and tear and normal maintenance, most owners of housing properties manage to maintain their properties in unchanged condition. In other words, this method deals with the fundamental identification problem for unique assets largely by assuming away depreciation and other sorts of quality change for existing homes. The originators were well aware of this limitation.[27]

---

[26] The repeat sales procedure, now in widespread use, dates back to Bailey, Muth, and Nourse (1963). See also Dreiman and Pennington-Cross (2004) for the uses of this method and see Green and Malpezzi (2003, pp. 32-60) for a review of the repeat sales index literature. Case and Shiller (1989) refined the methodology to control for heteroskedastic errors. The problem is that the size of the errors is related to the time in between sales, and this violates the assumption of equal error variances in least squares regression.

[27] Another assumption implicit in the repeat sales method is that attribute prices remain constant between sales so that the attribute prices cancel out in the construction of the house price index. The repeat sales approach has become practically the industry standard. Fannie Mae and Freddie Mac have combined their transaction data, and OFHEO publishes the resulting house price indexes at the national, regional, state and large metropolitan levels on a quarterly basis. Even if the OFHEO index or the closely related Freddie Mac index do not perfectly control for quality changes, the fact that they are updated every quarter for such a wide range of geographies (and are free) has made them the house price indexes of choice in research. Wolverton and Senteza (2000) note there are problems with the repeat sales method with respect to controlling for atypical maintenance and capital improvements. Using the U.S. National Association of Realtors (NAR) data that include information on sale prices, locations and

As originally proposed, the repeat sales method can only be used to measure price level change over time. No information on price levels can be derived from the pure repeat sales method as originally developed, making spatial comparisons of housing price levels impossible by this means. In the literature on spatial price level comparisons, Summers (1973) proposed a simple type of hedonic regression model where the only explanatory variables are dummy variables for the country and the commodity. As presented in the literature, the repeat sales and CPD methods appear very different, but Diewert (2003a) shows they are closely related.

Hedonic regression models work with price levels rather than price ratios as dependent variables, as is the case for the repeat sales method. For relating the Bailey-Muth-Nourse repeat sales procedure to hedonic approaches, Diewert (2003a) explains that it is helpful to introduce the method as it arose historically: as a generalization of the *chained matched model methodology* that was used by the early pioneers[28] in the construction of real estate price indexes. (See box 4.) Diewert (2003a) shows that the repeat sales method can be recast in a CPD framework. He then goes on to show the relationships to a general hedonic regression model[29] for housing. Thus all that has been learned about the CPD method applies for the repeat sales method. The much broader applicability of this method is established by Diewert (2003a).[30]

4.2 More General Hedonic Models

The weighted repeat sales house price method is attractive partly because different analysts should produce the same results if given the same data. The acceptance of this methodology rests, secondly, on the presumption that repeat sales price indexes do a better job of holding quality constant than alternative approaches. And, Malpezzi (2002) and others note that this method is popular with real estate researchers and practitioners because it uses only the information readily available in all localities for a country like the United States: the sale price, location, and legal property identification information needed to register the sale. However, when information *is* available about dwelling characteristics such as floor space, number of bathrooms, number of bedrooms, and so on, there is obvious interest in utilizing the information.

characteristics of 5581 dwellings sold in the years 1986 - 1992, Mills and Simenauer (1996) estimate that more than half of dwelling price increases during their analysis period resulted from quality improvements.

[28] See Wyngarden (1927) and Wenzlick (1952).

[29] The main features of a general hedonic regression model were laid out in Court (1939). This publication was not readily available to researchers and so the technique was not used widely until the work of Griliches (1971a, 1971b) popularized the technique. See Triplett (2004) for a systematic review of hedonic regression methods.

[30] Rao (2008) notes that the CPD method, the weighted version in particular, is being increasingly used in deriving spatial comparisons due to its ability to handle price quotations. See, for example, Aten and Menezes (2002), Heston and Atten (2002), Rao (2003, 2005), and Deaton, Friedman and Alatas (2004).

Box 4. An Exposition of the Repeat Sales Method

As in Diewert (2003a), let S(0,1) denote the set of housing units that are in scope for the index and were sold in both periods 0 and 1. Denote the price for property n sold in period t by V_n^t. Here attention is confined to just two time periods 0 and 1, so $n \in S(0,1)$. Let $P^{0,1}$ be the real estate price index going from period 0 to 1. For the housing units in S(0,1), suppose the stochastic model relating the property sales price ratio, V_n^1/V_n^0, to $P^{0,1}$ is:

(2-16) $$V_n^1/V_n^0 = P^{0,1} \exp \varepsilon_n^{0,1},$$

where $\varepsilon_n^{0,1}$ is assumed to be an independently distributed error term with mean 0 and constant variance. Taking logarithms of both sides of (2-16) leads to the following linear regression model:

(2-17) $$\ln[V_n^1/V_n^0] = \pi^{0,1} + \varepsilon_n^{0,1},$$

where $\pi^{0,1} \equiv \ln P^{0,1}$. The least squares estimator for $\pi^{0,1}$ is the arithmetic average of the logarithms of the sales price ratios. Exponentiating this estimator yields a preliminary matched model property price index going from period 0 to 1:

(2-18) $$P^{0,1*} \equiv \prod_{n \in S(0,1)} [V_n^1/V_n^0]^{1/N(0,1)},$$

where N(0,1) is the number of houses in the set S(0,1). This index is seen to be the equally weighted geometric mean of sales price ratios V_n^1/V_n^0 for all the properties that changed hands in both periods 0 and 1: a typical matched model estimator for an elementary price index.

Next consider the set S(1,2) of houses that sold in both periods 1 and 2. Now the resulting preliminary matched model property price index going from period 1 to 2 can be shown to be:

(2-19) $$P^{1,2*} \equiv \prod_{n \in S(1,2)} [V_n^2/V_n^1]^{1/N(1,2)}$$

where N(1,2) is the number of sales of houses in the set S(1,2).

Using the above results, the *levels* of the property price index, P^t, for periods t = 0,1,2 can be defined as:

(2-20) $$P^0 \equiv 1;\ P^1 \equiv P^{0,1*};\ P^2 \equiv P^{0,1*} P^{1,2*}.$$

Thus the price index P^t is set equal to 1 in the base period 0; in period 1, it equals the estimated matched model price index going from period 0 to 1, and in period 2, it equals the product of the preliminary matched model price indexes given in (2-18) and (2-19).

The Bailey, Muth and Nourse (BMN) innovation was to reparameterize the model described above and to add an additional set of estimating equations for repeat sales pairs in periods 0 and 2: i.e., for housing properties in S(0,2). The BMN estimating equations with three periods of data on repeat sales are the following ones:

(2-21) $$\ln[V_n^1/V_n^0] = \pi^1 - \pi^0 + \varepsilon_n^{0,1} \qquad \text{for } n \in S(0,1),$$

(2-22) $$\ln[V_n^2/V_n^1] = \pi^2 - \pi^1 + \varepsilon_n^{1,2} \qquad \text{for } n \in S(1,2),$$

(2-23) $$\ln[V_n^2/V_n^0] = \pi^2 - \pi^0 + \varepsilon_n^{0,2} \qquad \text{for } n \in S(0,2),$$

where now we have

(2-24) $$\pi^0 \equiv \ln P^0,\ \pi^1 \equiv \ln P^1, \text{ and } \pi^2 \equiv \ln P^2,$$

with the following normalization imposed (where adding a constant to each π^t leaves the regression unchanged):

(2-25) $$\pi^0 = 0 \quad \text{or} \quad P^0 = 1.$$

This leads to a model that can be estimated using least squares regression. Exponentiating the least squares estimates for the parameters π^1 and π^2, denoted here by π^{1*} and π^{2*}, leads to estimates for the preliminary indexes P^{1*} and P^{2*}. The BMN estimates for the housing price levels in the three periods are:

(2-26) $$P^0 \equiv 1,\ P^{1*} \equiv \exp \pi^{1*},\ P^{2*} \equiv \exp \pi^{2*}.$$

The three period model generalizes readily to the T period case considered by Bailey, Muth and Nourse (1963).

Box 5. The CPD Model with Complete Matched Model Data

Consider a sample of N houses ($n=1,2,\ldots,N$) each of which sold in each of the three periods ($t=0,1,2$): $S(0,1,2)$. A stochastic model for the house prices, V_n^t , in each period t can be specified as follows:

(2-27) $$V_n^t = \alpha_n P^t \exp \varepsilon_n^t , \qquad n=1,\ldots,N,$$

where P^t is the housing price index level for period t, α_n is a parameter that reflects the quality of housing unit n relative to "average" quality and ε_n^t is an independently distributed, mean zero, constant variance error term. Taking logarithms of both sides of (2-27) leads to the following system of estimating equations for the N houses:

(2-28) $$\ln V_n^t = \beta_n + \pi^t + \varepsilon_n^t , \qquad n=1,\ldots,N, \ t=0,1,2 .$$

where $\beta_n \equiv \ln \alpha_n$ and $\pi^t \equiv \ln P^t$. Diewert (2003a) shows that, for the model defined by (2-28) and the normalization (2-25), the least squares (LS) estimators for the model parameters satisfy the following N+2 equations:

(2-29) $$\sum_{n=1}^N \ln V_n^1 = \sum_{n=1}^N \beta_n^* + N\pi^{1*} ,$$

(2-30) $$\sum_{n=1}^N \ln V_n^2 = \sum_{n=1}^N \beta_n^* + N\pi^{2*} , \text{ and}$$

(2-31) $$\ln V_n^0 + \ln V_n^1 + \ln V_n^2 = 3\beta_n^* + \pi^{1*} + \pi^{2*} , \qquad n=1,\ldots,N .$$

Using equations (2-31) to eliminate the β_n^* from (2-29) and (2-30) yields the following solutions for the unknowns:

(2-32) $$\pi^{1*} = (1/N)\sum_{n=1}^N \ln[V_n^1 / V_n^0], \quad \pi^{2*} = (1/N)\sum_{n=1}^N \ln[V_n^2 / V_n^0] .$$

After exponentiating these estimates, this complete information CPD model leads to the following geometric mean of the period 1 relative to the corresponding period 0 values as the estimate for the period 1 housing price level, P^{1*}, and the geometric mean of the period 2 values relative to the corresponding period 0 values as the estimate for P^{2*} :

(2-33) $$P^{1*} = \prod_{n=1}^N [V_n^1 / V_n^0]^{1/N}, \quad P^{2*} = \prod_{n=1}^N [V_n^2 / V_n^0]^{1/N} .$$

At first glance, it seems that the CPD method (and by extension, unweighted hedonic regression methods) for comparing prices between countries (or time periods) are totally unrelated to traditional index number methods for making price comparisons. However, in a series of related papers, Diewert (2002, 2003a, 2003b, 2004, 2005b, 2006a, 2006b) and Diewert, Heravi and Silver (2007) show how alternative specifications and weights can be used within the CPD framework to derive a number of known index number formulae.[31]

Also, some homes transact twice in a period of months and others do not transact for decades.[32] Sellers of properties often undertake renovations and repairs just before putting their properties on the market.[33]

[31] For example, exponentiating (2-42) in box 6 reveals that this simple hedonic regression model, where each housing unit has only a single dummy variable characteristic, leads to a period 0 to 1 price index that is equal to the equally weighted geometric mean of the selling prices in period 1 divided by the geometric mean of the corresponding selling prices of the matched models in period 0. See also de Haan (2003), Silver (2003) and Silver and Hervari (2005). Diewert (2005b) shows that the unweighted indexes can be very far from their weighted counterparts. Thus it is important to run appropriately weighted regressions for obtaining estimates of price indexes.

[32] See, for example, Case and Quigley (1991).

[33] Dreiman and Pennington-Cross present evidence of this, and show that the house price variance differs by price tier and the length of time between successive sales of a property.

Box 6. The CPD Model with Incomplete Matched Model Data

Next a model is considered where *not* every house must trade in each period for information about the house to be included in the analysis data set. In order to minimize notational complexities, Diewert (2003a) provides the following details for the case of two periods. Let S(0,1) be the set of housing units that sold in both periods 0 and 1. Taking into account the normalization (2-25), the estimating equations corresponding to these houses are:

(2-34) $$\ln V_n^0 = \beta_n + u_n^0, \qquad \text{for } n \in S(0,1),$$

(2-35) $$\ln V_n^1 = \beta_n + \pi^1 + u_n^1 \qquad \text{for } n \in S(0,1).$$

Let S(0,~1) denote the set of housing units in the target population that sold in period 0 but not in period 1. The estimating equations for these observations are:

(2-36) $$\ln V_m^0 = \gamma_m + u_m^0, \qquad \text{for } m \in S(0,\sim 1),$$

where γ_m is the logarithm of the quality adjustment factor for the mth housing unit that sold in period 0 but not in period 1. Similarly, let S(1,~0) denote the set of housing units in the target population that sold in period 1 but not in period 0. The estimating equations for these observations are:

(2-37) $$\ln V_k^1 = \delta_k + u_k^0 \qquad \text{for } k \in S(1,\sim 0),$$

where δ_k is the logarithm of the quality adjustment factor for the kth housing unit that sold in period 1 but not 0.

Let π^{1*}, β_n^*, γ_m^* and δ_k^* denote the LS estimates of the parameters π^1, β_n, γ_m and δ_k that appear in (2-34)-(2-37). The stacked vector of dependent variables for equations (2-34)-(2-37) can be written as the sum of the vectors of exogenous variables times their corresponding least squares estimates plus the vector of least squares residuals. As noted above, the inner product of each exogenous vector with the vector of LS residuals is zero. Thus the LS estimators for the unknown parameters in the regression model must satisfy the following equations:

(2-38) $$\sum_{n \in S(0,1)} \ln V_n^1 + \sum_{k \in S(1,\sim 0)} \ln V_k^1 = \sum_{n \in S(0,1)} \beta_n^* + N(0,1)\pi^{1*} + \sum_{k \in S(1\sim 0)} \delta_k^* + N(1,\sim 0)\pi^{1*};$$

(2-39) $$\ln V_n^0 + \ln V_n^1 = 2\beta_n^* + \pi^{1*}, \qquad \text{for } n \in S(0,1)$$

(2-40) $$\ln V_m^0 = \gamma_m^*, \qquad \text{for } m \in S(0,\sim 1),$$

(2-41) $$\ln V_k^1 = \delta_k^*, \qquad \text{for } k \in S(1,\sim 0),$$

where N(0,1) is the number of dwellings that traded in both periods and N(1,~0) is the number that sold in 1 but not 0. Equations (2-41) can be used to eliminate the δ_k^* in equation (2-38), and equations (2-39) can be used to eliminate the β_n^* from equation (2-38). The resulting equation for π^{1*} is:

(2-42) $$\pi^{1*} = [1/N(0,1)] \sum_{n \in S(0,1)} \ln[V_n^1 / V_n^0],$$

which is the arithmetic average of the logarithms of the sales price ratios for the matched models in the two periods.

For the housing units that sold (or were rented) in period t, a more general hedonic regression model is:

(2-43) $$\ln V_n^t = \pi^t + \sum_{k=1}^{K} z_{nk}^t \beta_k + \varepsilon_n^t, \qquad n \in S(t).$$

ε_n^t is an independently distributed error term with mean 0 and constant variance, V_n^t is the observed selling price (or rent) of housing unit n in period t, z_{nk}^t is the amount of characteristic k that housing unit n possesses, and π^t equals the logarithm of the constant quality price index for period t, P^t; i.e., $\pi^t = \ln P^t$ for t = 0,1,…,T. The parameter β_k transforms amounts of the kth characteristic z_k into constant quality utility units for k = 1,…,K.

To correct for quality change contamination when using the repeat sales method to measure OOH price change, one way is to remove all observations where available information suggests there have been renovations that go beyond normal upkeep.[34] Another alternative is to use information, when available, about dwelling characteristics to correct for renovation related changes using a general hedonic regression model.[35]

Diewert (2003a; see box 5 for details) shows how the repeat sales approach can be modified to incorporate hedonic regression corrections for changes in observed characteristics of dwellings since they were last on sold. The resulting linear regression model (equations (2-34)-(2-37) in box 6) is the same as the two country version of Summers' (1973) *country product dummy model* (with incomplete information); it is also identical to the two period case of the Aizcorbe, Corrado and Doms (2001) *dummy product hedonic regression model*.[36]

In its basic form, the hedonic method usually involves regressing the logarithm of the property sale price on the characteristics of the property and a time dummy variable for each period spanned by the estimation data set (except the omitted base period). Once the estimation has been completed, the time dummy coefficients can be exponentiated to create an index.

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.

Using information on the characteristics of the properties sold, the data could also be stratified and a separate regression can be run for specified classes of residential properties. Thus the hedonic regression method could be used to produce a family of indexes.[37] Diewert, Heravi and Silver (2007) outline alternative formulations and establish the relationships among them.[38]

A potential advantage of the general hedonic regression model is that it uses all available observations on housing sales in each period in a nontrivial way whereas the repeat sales model does not use any information at all on sales that take place in only one of the sample periods.[39] It is intuitively obvious that when an observation has its very own dummy variable in a linear

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[34] For example, Case and Shiller (1989, pp. 125-126) use a variant of the repeat sales method with U.S. data on house sales in four major cities over the years of 1970-1986. They attempted to deal with the depreciation and renovation problems by removing houses with quality changes from the data set.

[35] A number of hybrid approaches have been developed over the years that attempt to incorporate the best of both worlds for hedonic and repeat sales indexes. The main obstacle to widespread acceptance is usually lack of data, but for customized purposes these innovations can be useful. Gatzlaff and Ling (1994) tested an assessed value technique. The idea is to broaden the repeat sales sample to include single-sale properties by using an assessed value in place of a second sales value. The assessed value comes from property tax records, and the underlying assumption is that those assessments are unbiased. The OFHEO indexes are available online at: http://www.ofheo.gov/house/. The Freddie Mac index is found at: http://www.freddiemac.com/finance/cmhpi/faq.htm.

[36] See also Aizcorbe and Pho (2008) in this volume.

[37] It is worth noting that a perceived advantage of the stratification method is that *median* price changes can be measured. 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.

[38] The connections between weighted hedonic regressions and weighted index number formulae are established in a vast literature including Diewert (2003c, 2004, 2005b), de Haan (2003), Silver (2003) and Silver and Heravi (2005). Predicted prices can then be generated in each period using the estimated hedonic regressions based on a constant characteristics set, such as 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 constant current period characteristics could also be compiled, as could such indexes based on a symmetric use of base and current period information.

[39] The latter is also a feature of the CPD model, as originally developed for international price level comparisons.

regression model, then this observation is not used to determine any of the other parameters in the model. If the unmatched prices in the sample of housing prices behave differently than the matched prices, then a general hedonic regression model can generate quite different price indexes than models that rely only on matched prices.

Determining which dwelling characteristics should be included is a challenge when applying the general hedonic regression model. Some variables might be included as well for the household type since there is evidence of systematic dwelling maintenance differences by household characteristics such as whether the owner occupier(s) are over 75 years of age.[40] For many data sets, there are literally hundreds of potential housing and owner/household characteristics that could be included on the right hand side.[41] The variable and functional form and pre-estimation data pooling or stratification choices constitute, in effect, the criteria under which properties will be judged to be comparable for the measurement of the housing price level and price level change.[42]

5. The Structures and Land Decomposition Problem[43]

Usually the logarithm of the purchase price is taken as the dependent variable in real estate price models. While this specification accords with the directly observable property price information, it is inconsistent with certain aspects of the structure and land components of the price of a property. As Diewert (2003a, 2006a) explains, residential real estate is typically a *composite* good; i.e., two distinct commodities are bundled together and sold (or rented) at a single price. The two distinct commodities are: (1) the structure, and (2) the land that the structure sits on (the site). To model this composite, consider a sample of dwelling units

[40] The Federal Housing Administration (FHA) insures reverse mortgages, called Home Equity Conversion Mortgages (HECM), which allow older owners to convert house equity into cash. The owners do not need to pay off the reverse mortgages until they move or permanently leave their homes, and then the property is sold to pay off the loan. These mortgages help older owners afford to stay on in their homes. Private lenders had been reluctant to offer reverse mortgages at affordable rates due to the uncertainty of repayment. Without a reverse mortgage being involved, an owner has a financial incentive to spend on maintenance when that spending can be expected to increase the house value and owner equity. However, if the owner has a reverse mortgage, the owner cannot benefit financially unless they are allowed to increase their borrowing against the house value if renovations cause the house to appreciate. In fact, the owner's financial incentives are to minimize maintenance spending unless this threatens to shorten how long they can stay in the home. See Davidoff and Welke (2004). Also, based on estimations from the Health and Retirement Survey (HRS), Rodda and Patrabansh (2005) report that the house values of elderly (75 years or more) owners appreciate in real terms at 1.0 to 1.2 percentage points less per year than the houses of middle-aged (50 to 74 year old) owners. These estimates are smaller than the findings by Davidoff (2004) who used the American Housing Survey to show 3 percentage point slower appreciation for owners aged more than 75 relative to all other owners. The most direct explanation for the older ages discount is that the homes of older owners are out-of-date in style and frequently poorly maintained. Without regular maintenance and occasional remodelling, a house gets discounted in the market compared to newer homes that match buyers' preferences.

[41] Butler (1982) and Ozanne and Malpezzi (1985) demonstrate that coefficient estimates are not normally robust with respect to omitted variables, but the index outcomes may be more robust. See Li, Prud'homme and Yu (2007), and also Diewert, Heravi and Silver (2007).

[42] Another problem that has not been discussed is the possibility that house sale prices might exhibit seasonal fluctuations. The general hedonic regression model could be modified to include seasonal dummy variables.

[43] Discussions between Erwin Diewert and Anne Laferrère helped improve the presentation of the model here.

purchased at the beginning of period 0. Suppose the purchase price of property n is p_n^t, where here and in box 7 we abstract from depreciation and property age issues (so there is no sub v).

The value for property n can be regarded as the sum of the (often unobserved) cost per square meter for the structure, times the floor space of the structure in square meters (denoted by A in box 7), plus the price per square meter of land (often not directly observed) times the area of the site in square meters (denoted by B in box 7). For period 0, the property value can be represented as in equation (2-45) in box 7, and for period t, the value for this property can be represented as in equation (2-46). The structure and land components are usually subject to different rates of inflation, and the depreciation rates will usually differ too since land depreciates little if at all (though there can be depreciation of site infrastructure such as drainage works). The asset inflation and depreciation effects are embedded in the coefficients of A and B.[44] Estimating equations are given by (2-47) and (2-48) in box 7. If data are available for the characteristics of the structure and the land, then the pair of equations shown in (2-49) and (2-50) can be estimated instead. This model is flexible and provides a means of decomposing a property price index into structural and land components (though the model is highly nonlinear).

6. Further Thoughts on User Costs versus Rental Equivalence

Dougherty and van Order (1982), who helped popularize the user cost approach in the real estate literature, state that, in a competitive economy, the per period user cost should be equal to the per period rental price charged for a dwelling by a profit maximizing landlord. Thus, the observable rental value is asserted to equal the user cost. And Ceccheti (2007) writes that:

> "[Owner equivalent rent] really is the current opportunity cost of the house. It measures the income I could receive if I were to vacate my current living space and rent it to someone else."

However, we argued in section 2.5 that the usual user cost referred to above by Ceccheti is not quite the full opportunity cost of the house; the full opportunity cost is the maximum of the user cost and the market rent that the house could fetch.

We also saw earlier that there is a considerable amount of empirical evidence that the usual user costs and market rents do not always closely approximate each other. In fact, Garner and Verbrugge (2008) claim to show that rents and property values sometimes move quite differently:[45]

> "What is the per period cost of owning a durable good? For long lived durable goods, there are two commonly proposed measures: rent, and user costs. In simple frictionless theory, these measures are equivalent. Yet here and in Verbrugge (2006) we demonstrate that, in the U.S. housing data, these measures diverge markedly, over extended periods of time...."

[44] 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 errors compared to very inexpensive properties.

[45] See Verbrugge (2006) who discussed (and dismissed) a possible alternative explanation for this divergence.

Box 7. Structure and Land Decomposition

Suppose the total cost, p, of a property after the structure is completed will equal the floor space area of the structure, say A square meters, times the building cost per square meter, α say, plus the cost of the land, which will equal the cost per square meter, β say, times the area of the land site, B. Now think of a sample of properties of the same general type, with prices, p_n^0, in period 0 and structure areas A_n^0 and land areas B_n^0 for $n=1,\ldots,N(0)$, and where these prices are equal to costs of the above type times error terms η_n^0 which have mean 1. This leads to a hedonic regression model for period 0 where α and β are the parameters to be estimated in the regression:

(2-45) $$p_n^0=[\alpha A_n^0+\beta B_n^0]\eta_n^0 .$$

Taking logarithms of both sides of (2-45) leads to the following traditional additive errors regression model:

(2-46) $$\ln p_n^0=\ln[\alpha A_n^0+\beta B_n^0]+\varepsilon_n^0 ,$$

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

For a subsequent period t, the price per square meter for the given type of structure will have changed from α to $\alpha\gamma^t$ and the land cost per square meter will have changed from β to $\beta\delta^t$ where γ^t is the *period 0 to t price index for the type of structure* and δ^t as the *period 0 to t price index for the land that is associated with this type of structure*. For $n=1,\ldots,N(t)$, the period t counterparts to (2-45) and (2-46) are:

(2-47) $$p_n^t=[\alpha\gamma^t A_n^t+\beta\delta^t B_n^t]\eta_n^t \text{ and}$$

(2-48) $$\ln p_n^t=\ln[\alpha\gamma^t A_n^t+\beta\delta^t B_n^t]+\varepsilon_n^t ,$$

where $\varepsilon_n^t\equiv\ln\eta_n^t$, the period t property prices are p_n^t, and the structure and land areas are A_n^t and B_n^t.

Diewert (2006a) suggests that equations (2-46) and (2-48) can be run as a system of nonlinear hedonic regressions. The main parameters of interest are γ^t and δ^t, which can be interpreted as period t price indexes (relative to the corresponding period 0 price levels of 1) for the price of a square meter of this type of structure and the price per meter squared of the underlying land.

This framework can be generalized to encompass the traditional array of characteristics used in real estate hedonic regressions. Suppose that we can associate with each property n that is transacted in t a list of K price determining characteristics $X_{n1}^t,X_{n2}^t,\ldots,X_{nK}^t$ for the structure and a similar list of M price determining characteristics $Y_{n1}^t,Y_{n2}^t,\ldots,Y_{nM}^t$ for the type of land. The equations that generalize (2-46) and (2-48) are:

(2-49) $$\ln p_n^0=\ln\{[\alpha_0+\textstyle\sum_{k=1}^K X_{nk}^0\alpha_k]A_n^0+[\beta_0+\sum_{m=1}^M Y_{nm}^0\beta_m]B_n^0\}+\varepsilon_n^0 , \qquad n=1,\ldots,N(0) \text{ and}$$

(2-50) $$\ln p_n^t=\ln\{\gamma^t[\alpha_0+\textstyle\sum_{k=1}^K X_{nk}^t\alpha_k]A_n^t+\delta^t[\beta_0+\sum_{m=1}^M Y_{nm}^t\beta_m]B_n^t\}+\varepsilon_n^t , \ n=1,\ldots,N(t) ,$$

where the parameters to be estimated are now the K+1 quality of structure parameters, $\alpha_0,\alpha_1,\ldots,\alpha_K$, the M+1 quality of land parameters, $\beta_0,\beta_1,\ldots,\beta_M$, the period t price index for structures parameter γ^t and the period t price index for the land underlying the structures parameter δ^t. Note that $[\alpha_0+\sum_{k=1}^K X_{nk}^0\alpha_k]$ in (2-49) and (2-50) replaces the single structures quality parameter α in (2-46) and (2-48) and $[\beta_0+\sum_{m=1}^M Y_{nm}^0\beta_m]$ in (2-49) and (2-50) replaces the single land quality parameter β in (2-46) and (2-48).

How do Garner and Verbrugge (2008) and Verbrugge (2006) arrive at the above conclusions? The key is the user cost forecasting equation from Verbrugge's 2006 paper. He starts off with the following expression for the user cost u_i^t of home i:[46]

(2-60) $$u_i^t = P_i^t(i^t + \delta - E\pi_i^t)$$

where P_i^t is the price of home i in period t; i^t is a nominal interest rate;[47] δ is the sum of annual depreciation, maintenance and repair, insurance, property taxes and potentially a risk premium;[48] and $E\pi_i^t$ is the period t expected annual (constant quality) home appreciation rate for home i.[49] 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 (2-60) in order to determine the rent for a tenant.[50] So far, there is nothing particularly controversial about Verbrugge's analysis. What is controversial is his determination of the expected house price appreciation term, $E\pi_i^t$. Verbrugge (2006, p. 12) writes that:

> "Rather than using a crude proxy, I will construct a *forecast* for $E\pi_i^t$...."

Verbrugge goes on to use various econometric techniques to forecast expected price appreciation for his one year horizon. He inserts these forecasts into the user cost formula (2-60) above and obtains tremendously volatile ex ante user costs, and the rest of his conclusions follow.

Diewert (2006a, pp. 24-25) gives two reasons why it is unlikely that landlords set their rental rates based on short term forecasts of housing price appreciation. His first reason is that housing tenure data reveal that a typical owner occupier holds their property for 6 to 12 years. Given this and the known costs for households of moving (including non monetary costs such as disrupting the friendship and school situations of children), he argues that owners can be expected to plan using in terms of an annualized average rate of price appreciation averaged over at least 6 years. In contrast, the Verbrugge (2006) and Garner and Verbrugge (2008) studies estimate a property appreciation rate based on a one year time horizon. Diewert (2003a) suggests that one 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.[51]

[46] See formula (1) in Verbrugge (2006, p. 11). His notation is not followed exactly here.

[47] Verbrugge (2006, p. 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.

[48] Verbrugge (2006, p. 13) assumed that δ was approximately equal to 7 %.

[49] π_i^t is the actual 4 quarter (constant quality) home price appreciation between the beginning of period t and one year from this period.

[50] 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.

[51] See Guðnason and Jónsdóttir (2008, chapter 5, this volume).

Diewert also argues that 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," writes Diewert (2003a).[52] It is however possible that landlords may have some idea of the long run 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 (2-60).

Gordon and van Goethem (2004) note that rental rate stickiness has been shown to be particularly great for tenants continuing on from the previous year, which is the case for the majority of tenants.[53] Gordon and van Goethem (2004) argue too that societal and political forces have resulted in tax laws that transfer the benefits of capital gains to landlords, at least in the short run.[54] They muse that we might expect, in the long run, that capital gains on rental properties, as well as tax deductions available to landlords, would translate into increasing supplies and falling real rental rates. Yet Gordon and van Goethem (2004) cite evidence that this translation has been taking place slowly, when at all, in most localities in the United States. Gordon and van Goethem (2004) go on to state that they have, nevertheless, finally found a convincing explanation in a paper by Díaz and Luengo-Prado (2003) for sticky rent behaviour.

The basic thesis of the Díaz and Luengo-Prado paper is that adjustment costs, uncertainty, tax deductibility, down payment percentages, and discount rates prevent most Americans who are renters from switching to owned accommodations, thereby making it unnecessary for landlords to reduce their rents to hold these tenants.[55] This conclusion is referred to by Gordon and van Goethem (2004) as "a convincing explanation of a fundamental puzzle...."

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[52] Diewert (2006a, p. 24) writes that it is nevertheless also "possible that landlords may have some idea of the long run 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."

[53] See, for example, the findings of Genesove (1999). Also, Hoffmann and Kurz-Kim (2006, p. 5) report the following: "In Germany, as in other euro area countries, prices of most products change infrequently, but not incrementally.... In our sample, prices last on average more than two years... but then change by nearly 10 %. The longest price durations are found for housing rents, which, on average, are for more than four years." And also, Hoffmann and Kurz-Kim (2006, p.5) 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 %. The longest price durations are found for housing rents, which, on average, are for more than four years."

[54] Sinai and Souleles (2003) argue that rent risk is another reason why most households indicate by their choices and on surveys that they would prefer to be in owned housing. The underlying model is a tenure choice model in which the renter faces uncertain rent changes each year but no risk of capital loss when the renter moves. Owners, on the other hand, can avoid uncertain annual increases by purchasing a house with a fixed rate mortgage. There is still the risk of capital loss when the owner finally sells the property, but the longer the holding period the more that future risk is discounted. Moreover, the owner only faces that risk at the end of the holding period, whereas the renter faces some ongoing risk of rent increases, with the nature of this risk being loosely bounded by formal rental agreements, customs, and landlord fears of rent controls. The renter's risk is that rents will go up and the owner's risk is that prices will go down. Sinai and Souleles (2003) claim to show that rent risk dominates house price risk, which means households use ownership to shield against rent increases. In finance language, households can hedge against rent risk by buying their home. The demand for homeownership increases with the expected holding period and the cumulative rent volatility (i.e., rent volatility during the holding period), but decreases with house price volatility.

[55] Gordon and van Goethem (2004) remind us that a large proportion of renters are young, have not yet saved the down payment necessary for home ownership, move too often to allow the advantages of home ownership to offset transition costs, and are subject to capital market constraints based on their current incomes and poor credit histories.

As we understand their results, however, the Díaz and Luengo-Prado conclusions, if correct, only provide an explanation for *downward* rent stickiness; their results do *not* provide an answer to the question of what keeps landlords from *raising rents* much more, and more frequently, than they are generally observed to do.

We suggest two possible fear factors that might explain upward rent stickiness. One is that, when rental markets become tight and rents start to rise, the possibility of rent controls being enacted or strengthened is an ever present threat for landlords. Once rent controls are brought in, it can take years or even decades for opponents to get rid of them again. A second is that the often invisible hand of renter rage could be an influence on landlords in setting rental rates, even for incumbent tenants.[56]

7. How We See the Options

For official statisticians who are persuaded that shelter should be included in a CPI, including owner occupied shelter, and who are persuaded of the merits of pricing the *use* of shelter services rather than the acquisition or purchase of properties, the evidence and arguments covered in this paper suggest the following choices, depending on the measurement objectives.

For a nation interested in producing a single national CPI that reflects the consumption price experience for a representative (e.g., a median) household, it seems to us that the opportunity cost approach is the most satisfactory one. There are two distinct opportunity costs associated with home ownership, namely (1) the financial opportunity cost which is the traditional user cost concept and (2) the opportunity cost of renting out the dwelling unit which is the market equivalent rent concept.

Alternatively, in recognition of the large role that housing ownership status plays in shaping other household consumption options and patterns, the known barriers to movement into owned housing for many renters, and the low rates of transition from renting to owning or from owning to renting for most demographic groupings of adults, a nation could produce separate CPI indexes for households, depending on their rental or owner occupier status in the previous time period. The component for renters would simply follow rents as the main shelter price information. For owner occupiers, our preferred treatment is the *opportunity cost approach*, treating the effective opportunity cost of OOH as the *maximum* of the financial and rental opportunities costs.

In addition, of course, it would be useful for statistical agencies to also produce series based on the traditional user cost and rental equivalence approach as well as on the acquisitions approach for international comparability purposes, in the spirit of the Statistics Canada analytic

[56] Empirical evidence suggests that rental properties depreciate faster than owner occupied dwellings. The damage deposits landlords demand are not sufficient to cover the damages that some tenants inflict, and tenant grievance procedures often make it difficult for landlords to keep the damage deposits even when there is damage. It is well documented that landlords are more likely to increase rents, and more likely to institute bigger rent increases, for new tenants. However, landlords may face some of the same restraints as employers interested in instituting lower wage scales for newly hired workers. When the new tenants move in, if the property has incumbent tenants as well, the new ones will soon learn what the rental conditions are for those who came earlier. Tenant rage can take many forms that landlords may find difficult to prevent or obtain compensation for.

series program described by Baldwin, Nakamura and Prud'homme (2008). Data permitting, both the renter and the owner occupier CPI components should be quality adjusted using hedonic methods.

Appendix A. Early Developments in the Accounting Treatment of Depreciation

The earliest accounting profession approaches to depreciation were based on appraisals.

In the early 1900s, Middleditch (1918) devised a method for constructing a current value at the end of an accounting period. Suppose an asset was purchased new at the beginning of accounting period 0 at the price p_0^0, and that this asset is subject to a period 0 depreciation rate of δ^0 and a general rate of price inflation over period 0 of r^0; i.e., the general price level at the end of the period divided by the general price level at the beginning of the period is $1+r^0$. Then the *historical cost accounting value of the asset* at the end of the period is $(1+r^0)p_0^0$, but the *General Price Level Adjusted (GPLA) value* is: $V_{GPLA} \equiv (1-\delta^0)(1+r^0)p_0^0$.

Note the difference between r^0, an ex post general inflation rate, and the asset specific anticipated inflation rate i^0 defined as $(1+i^0) \equiv p_1^1/p_0^0$ where p_0^0 and p_1^1 are the price of the same asset at the beginning and end of the accounting period. In general, r^0 will not equal i^0 and hence the GPLA value for the asset will not equal its end of period market value (unless the general inflation rate r^0 is equal to the asset specific inflation rate i^0). This is the main weakness of General Price Level Adjusted accounting. However, its strength is that it will adjust for the effects of general inflation.

There is also the issue of how to choose the general inflation rate r^0. One of the simplest choices is to use the inflation rate for a widely traded commodity (such as gold) as the index of general inflation. Another alternative is to use the rate of increase in the exchange rate of the country against a stable currency. Instead of using the price of gold or any single commodity as the indicator of inflation, the general inflation between the beginning and the end of the accounting period might be better captured by looking at the price change of a "representative" basket of goods. As a further refinement, we could replace a fixed basket price index by a more general index such as the Fisher (1922), which allows for substitution in response to price changes.

The specific price level method for constructing current values for an asset held by a business unit through successive accounting periods was suggested by Daines (1929, p. 101), Sweeney (1934, p. 110) and many other accountants.[57] The method works as follows. First,

[57] "Inasmuch as the price level is not stable for any great length of time, and since this calculation is contemplated for each fiscal period, the only feasible procedure for a company with thousands of assets is the use of price index numbers" Bell (1953, p. 49). "Where no market exists for new fixed assets of the type used by the firm, two means of measuring current costs are available: (1) appraisal, and (2) the use of price index numbers for like fixed assets to adjust the original cost base to the level which would now have to be paid to purchase the asset in question."

assets held by the business unit at the beginning of period 0 are classified into a finite number of distinct asset classes. Secondly, it is supposed that index numbers that pertain to each asset class are available at the beginning and end of each accounting period. Finally, suppose that an asset was purchased at the beginning of accounting period 0 at the price p_0^0,[58] the period 0 depreciation rate is δ^0 and the asset inflation rate for the relevant asset class over period 0 is i^0 (i.e., the specific asset index number at the end of the period divided by the specific asset index number at the beginning of the period is $(1+i^0)$). Then the *Specific Price Level Adjusted (SPLA) value of the asset* at the end of period 0 is defined as: $V_{SPLA} \equiv (1-\delta^0)(1+i^0)P^0$. The present specific price index number method for constructing an end of period estimated asset value is very similar to the General Price Level Adjusted asset value; the only difference is that now a presumably more relevant specific price index is used for revaluation purposes.

Appendix B. 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. Van der Wal, ter Steege and Kroese (2006) describe how Statistics Netherlands uses appraisal information in order to construct a property price index. The *SPAR (Sales Price Appraisal Ratio) Method* has also been used in New Zealand since the early 1960s.[59] It makes use of *matched pairs*, but unlike the repeat sales method, the SPAR method utilizes nearly all the available transactions data, and hence should be less prone to sample selection bias. (See box 8 for details.)

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 = 1, and the appraisal for the base period of all dwellings that have been sold in the reference period.

Other variants of a SPAR type index can be defined. Diewert (2006a) defines the (regular) *Dutot, Carli and Jevons Market Value to Appraisal indexes* and discusses their alternative merits.

These appraisal methods rely on assessment information in the base period and sales information in the current period. The assessment methods use much more information than the repeat sales method. The analyst need not have separate information on housing or structure characteristics in order to implement this method. Rather, the information quality of these methods rests on the quality of the information and methods of the assessment authority.

Edwards and Bell (1961, p. 186). See also Chambers (1965). For modern methods, see Chinloy (1980) and Chinloy and Megbolugbe (1997).

[58] More generally, p_0^0 can be the estimated beginning of period 0 current value for the asset.

[59] For more detail, see Bourassa, Hoesli and Sun (2006). For material on appraisal quality, see Leventis (2006).

Box 8. A Method for Making Use of Assessment Data

Denote the number of sales of a given type of real estate in the base period 0 by N(0), the sales prices by $[p_1^0, p_2^0, \ldots, p_{N(0)}^0] \equiv p^0$, and the corresponding official appraisal prices by $[A_1^{00}, A_2^{00}, \ldots, A_{N(0)}^{00}] \equiv A^{00}$. The number of sales of the same type of property in the current period is denoted by N(t), the sales prices are denoted as $[p_1^t, p_2^t, \ldots, p_{N(t)}^t] \equiv p^t$, and the corresponding official appraisal prices are denoted by $[A_1^{0t}, A_2^{0t}, \ldots, A_{N(t)}^{0t}] \equiv A^{0t}$. The *value weighted SPAR index* (van der Wal, ter Steege and Kroese 2006, p. 4) can be written as:

(2-51) $$P_{DSPAR} \equiv [\sum_{i=1}^{N(t)} p_i^t / \sum_{i=1}^{N(t)} A_i^{0t}] / [\sum_{i=1}^{N(0)} p_i^0 / \sum_{i=1}^{N(0)} A_n^{00}] .$$

In the subscript for the index defined by (2-51), the D stands for Dutot, since the index formula on the right hand side is closely related to the Dutot formula that occurs in elementary index number theory. More specifically, if the term $\sum_{i=1}^{N(0)} A_n^{00} / \sum_{i=1}^{N(t)} A_n^{0t}$ equals 1, then the index reduces to a Dutot index (see ILO et al. 2004, chapter 20.). Diewert (2006a) suggests that one way to justify (2-51) is to suppose that the value p_n^0 for each property transacted in period 0 equals a common price level for that property type, P^0 say, times a quality adjustment factor, Q_n^0, so that:

(2-52) $$p_n^0 = P^0 Q_n^0 , \qquad n = 1,2,\ldots,N(0) .$$

Next, we assume that the period 0 assessed value for transacted property n $n=1,2,\ldots,N(0)$, denoted by 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, written as $1+\varepsilon_n^{00}$, where it is likely that the expected value for each of the error terms is 0. This stochastic specification reflects the fact that the errors are more likely multiplicative rather than additive. Thus:

(2-53) $$A_n^{00} = P^0 Q_n^0 (1+\varepsilon_n^{00}) ,$$

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

(2-54) $$E\varepsilon_n^{00} = 0 .$$

Suppose now that the value p_n^t for each property transaction in period t equals a common price level for the property type, P^t say, times a quality adjustment factor, Q_n^t say, so that:

(2-55) $$p_i^t = P^t Q_i^t .$$

Next, suppose that the period 0 assessed value for property i in period t, A_i^{0t}, equals the period 0 price level P^0 times the quality adjustment factor, Q_i^t, times an independently distributed error term, denoted by $1+\varepsilon_i^{0t}$. It is no longer likely that the expected value of the error term 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. Thus:

(2-56) $$A_i^{0t} = P^0 Q_i^t (1+\varepsilon_i^{0t}) .$$

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 for property n in total value of properties transacted in period 0, s_n^0, as follows:

(2-57) $$s_n^0 \equiv p_n^0 / \sum_{k=1}^{N(0)} p_k^0 .$$

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

(2-58) $$s_i^t \equiv p_i^0 / \sum_{k=1}^{N(t)} p_k^t \qquad i=1,2,\ldots,N(t)$$

Now substitute (2-52)-(2-56) into definition (2-51), use definitions (2-57) and (2-58), and we obtain:

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

(2-59) $$= [P^t / P^0][1+\sum_{k=1}^{N(0)} s_n^0 \varepsilon_n^{00}] / [1+\sum_{k=1}^{N(t)} s_n^t \varepsilon_n^{0t}] .$$

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