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WORKING PAPER NO. 99-9/R

MEASURING HOUSING SERVICES INFLATION

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Federal Reserve Bank of Philadelphia

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ABSTRACT

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Recent papers have questioned the accuracy of the Bureau of Labor Statistics' methodology for measuring implicit rents for owner-occupied housing. We propose cross-checking the BLS statistics using data on owner-occupied and rental housing from the American Housing Survey. A hedonic approach that explicitly calculates capitalization rates produces a methodologically consistent measure of the rental cost of owner-occupied housing. Applying this method, we find that between 1985 and 1993 the Consumer Price Index overstated the increase in the cost of owner-occupied housing services by more than 10 percentage points.

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MEASURING HOUSING SERVICES INFLATION

I. Introduction

In recent years, the accuracy and methodological consistency of alternative measures of U.S. inflation over time have been repeatedly questioned (for example, Gordon, 1990; Reinsdorf, 1993; Boskin et al., 1996; Griliches, 1994; Diewert and Fox, 1999; and Nakamura, 1996, 1999.) This paper proposes a hedonic methodology for consistently measuring inflation in housing services, the largest component in the U.S. Consumer Price Index (CPI).[1] This methodology is tested over the period from 1985 to 1993; the methodology can be extended backward to 1973 with American Housing Survey data and possibly back to 1940 with data from the decennial U.S. Censuses of Housing.

Housing services account for one-fourth of the CPI and one-seventh of U.S. personal consumption expenditures. Conceptually, there has long been agreement in the economics profession that the user cost of capital approach is the right one for measuring housing services.[2] Since 1983 the U.S. Bureau of Labor Statistics (BLS) has used the rental equivalent method for measuring the user cost of capital for owner-occupied housing; in this method, the inflation rate of rents for constant-quality rental units is used as a proxy for the inflation rate of the service flow to owner-occupied housing. Recently, however, observers have questioned whether the specific methods used by the BLS to measure rents have in practice been accurate and consistent (Boskin et al., 1996; Armknecht et al., 1995; Moulton, 1997). In this paper, we pose an

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[1]Note that the BLS does not attempt to make the CPI a consistently measured series. Stewart and Reed (1999) discuss this issue and construct a version of the CPI that is intended to be consistently measured, covering the period from 1978 to 1998.

[2]See Smith et al. (1988) for a discussion of the user cost of capital for owner-occupied and rental housing.

alternative to the rental equivalent method: to estimate the implied rental rate for owner-occupied housing using hedonic regressions and estimated capitalization rates of owner-occupied housing.

There are really two nested questions about the accuracy of the rental equivalent method that we attempt to address using hedonic methods. The first is how well the methodology of the BLS measures rental price inflation itself; the second is whether this index is a good proxy for inflation in owner-occupied housing.

How well has rental inflation been measured in the past by the BLS survey methodology? First, it is useful to note that rentals are measured using transactions prices as reported in tenant surveys and interviews, rather than posted prices.[3] Evaluating measured rental inflation by survey is complicated by at least four factors: 1) the quality of a given apartment is likely to change over time either because of imperfect maintenance or through improvements made by the landlord or tenant; 2) tenants' reports of changes in rents may be inaccurate; 3) tenants move, and vacant apartments may have a different inflation rate than continuously occupied ones; and 4) changes in BLS survey methodology and computational procedures occur over time.[4]

Assuming rental inflation has been measured accurately, is rental inflation a good proxy for the inflation rate of owner-occupied housing units?[5] Typical owner-occupied housing units have many characteristics that differ from units designed for rental; for example, owner-occupied

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[3]Most other prices in the CPI are measured using posted prices.

[4]The quality issue is complicated further by vintage effects (Randolph, 1988). The vacancy effect resulted in a major change in methodology in 1983; changes in prices for vacant apartments are now imputed (Rivers and Sommers, 1983 and Genesove, 1999).

[5]Aside from the issues discussed below, the formulas used by the BLS for calculating inflation rates for owner-occupied housing were flawed during the period 1988-1995 (Armknecht et al., 1995).

units are predominantly single-family detached units, while rental units are predominantly in multiple-unit buildings.[6] The BLS attempts to compensate for differences between the two types of units by oversampling rental units that have characteristics like those of owner-occupied housing. However, these oversampled units may not reflect typical owner-occupied units for several reasons. First, these units are often temporary rentals that drop out of the sample in a short time, so that reporting is spotty. Second, the market for these units is relatively thin, so that the observed rents may not be good proxies for the implicit value of the unit's service flow if it were an owner-occupied unit. Third, rental units are subject to double-sided moral hazard, which leads to long-term contracts and price regulation. Finally, the methods used by the BLS to measure rental inflation in individual units have evolved over time to correct for various measurement biases such as aging, tenants' imperfect recall of past rent increases, vacancies, and new units.

One way to check for the importance of these problems and the accuracy of solutions proposed would be to use an independent data set to construct benchmark measures of inflation. In this paper we develop separate price indexes for rental and owner-occupied units using hedonic methods. Using estimated capitalization rates, we then compute alternative estimates of the rate of inflation of housing services. The basic procedure is as follows. First, we estimate the value of service flow derived from each trait in the bundle of goods that we call housing services. These hedonic prices for bathrooms, basements, etc. are then used to construct constant-quality

[6]Linneman and Voith (1991) show that owners and renters tend to consume systematically different housing bundles and that their valuation of the flow of housing services may differ as well.

house price indexes for both rental and owner-occupied housing.[7] Using techniques developed in Linneman and Voith (1991), we estimate a capitalization rate for owner-occupied housing that yields an estimate of the value of the service flow from owner-occupied housing and thus allows the construction of a price index for housing services.

Implied capitalization rates are important for measuring inflation in housing services for two reasons: 1) the capitalization rates affect the relative weights of owner-occupied and renter-occupied housing in the consumer price index; and 2) changes in capitalization rates over time reflect changes in the user cost of capital and hence affect the inflation rates of owner-occupied housing services. Higher capitalization rates imply higher nominal valuation of owner-occupied housing services, and hence, the higher the capitalization rate, the more important the owner-occupied component in the price index of housing service flows. Increases in the capitalization rates over time will increase the measured rate of inflation in owner-occupied housing services, even if the prices of housing traits remain unchanged from one period to the next. While there is little reason to expect major changes in the capitalization rate over the period we examine (1985-93), it is quite possible that capitalization rates change significantly over other periods of time, although we do not investigate that question here.

Over the 1985-93 period, we find that BLS estimates of the rate of increase in the price of owner-occupied housing services is about 31 percent higher than our estimates using hedonic methods. BLS estimates of the rate of rental inflation, on the other hand, are 14 percent lower than our hedonic estimates. In addition, we find that the capitalization rates of owner-occupied

[7]Because we have data on the aggregate stock of housing traits, a useful byproduct of this analysis is that the change in the total value of rental and owner-occupied housing services over a given period can be decomposed into the price change and quantity changes.

housing were nearly identical in 1985 and 1993. Given our best estimate of the capitalization rate, we estimate that the overall price increase of housing services for the period was 33.4 percent, an average annual rate of 3.7 percent, which is lower than the CPI estimate of 40.0 percent, an average annual rate of 4.3 percent. Our best estimate agrees closely with the work of Moulton (1997), which corrects the CPI estimate for aging bias before 1988, misreporting, and computational errors in the owner's equivalent rent calculation before 1995.

The plan of the paper is as follows. Section two outlines the rental equivalent method of measuring housing services inflation used by the BLS. Section three outlines our proposed hedonic method, including the estimation of capitalization rates. Section four describes the data used in the hedonic analysis. Section five compares our measures of housing services inflation with those of the BLS. Section six concludes.

II. The BLS Methods for Measuring Inflation in Housing Services

Households derive a service flow from the housing stock in which they reside. In exchange for this service flow, households pay an explicit rent, or they may own the home in which they reside, in which case their rental payment is an implicit one. What we observe are rents in the first case and housing prices in the second. The BLS methodology for measuring changes in rents and the implied rent associated with owner-occupied housing has changed several times in the last quarter century.

BLS methodology prior to 1983. Prior to 1983, the BLS estimated the expenses of home ownership through estimates of individual cost components, such as mortgage interest costs, home purchase prices, insurance costs, and so forth. These home ownership expenses represented

the cost of housing for homeowners in the CPI. Home ownership expenses accounted for 14.3 percent of the CPI in December 1963, and rentals accounted for 5.5 percent of the index. Rental rates were estimated more directly. Prior to 1978, the Bureau of Labor Statistics measured rents by asking some 40,000 renters to mail rental forms back (monthly for the five largest urban areas and every three months for the other 51 urban areas sampled) giving the rental rates as of the 15th of each reported month. Beginning in 1978, the BLS began sampling tenant units on a six-month rotation involving 23,000 units. This slower rate of sampling takes into consideration the fact that rents typically change annually. When an apartment is sampled, the tenant is asked what the current month's rent is and what the previous month's rent had been. The two changes -- the current month change and the six-month change -- were then used to estimate the current month change in rent.[8]

BLS methodology after 1983. The BLS adopted the concept of owners' equivalent rent for the CPI in 1983 (Gillingham and Lane, 1982). For the period from 1983-86, owners' equivalent rent was calculated by reweighting the rent sample to represent owner-occupied units. From January 1987, the BLS began sampling rental units in the same neighborhoods and with the same structural attributes as owner-occupied units.[9] The empirical part of this paper

[8]Research by the BLS found that the one-month changes tended to underestimate rent change. One reason is apparently that rent changes often occur when the tenant changes, and the new tenant may not be aware that a rent change has taken place. However, even continuous-occupancy-tenant reports of one-month changes tended to be underreported. As a consequence, beginning in January 1995, the BLS revised its method to use the six-month change in rents as an estimate of the monthly rental change. That is, it estimates the one-month change as being the sixth root of the six-month change.

[9]Unfortunately, the rental units to which the owner-occupied units were matched were aggregated using a Sauerbeck formula, a formula that tends to cause a systematic overstatement of inflation (Armknecht et al., 1995). This overstatement is estimated by the BLS to have been

concentrates on the eight-year change in the price of housing services between 1985 and 1993. Table 1 includes the CPI indexes for these two years and the rates of change for renters' costs, homeowners' costs, and the total cost of housing services.

The major concerns about the BLS methods center on whether changes in rental rates are measured accurately and, if they are, whether they accurately reflect changes in the user cost of capital for residents of owner-occupied housing. With respect to measuring the changes in rental rates over time, the primary concern is whether the changes in reported rents reflect pure rental inflation--holding quality constant--or whether they also reflect changes in the service flow derived from the unit. It is a well-established fact that for rental properties, age is negatively related to price. This economic depreciation can be interpreted in one of two ways: that rental properties physically depreciate over time as a result of imperfect maintenance, or that embodied technological progress makes existing rental properties economically obsolete over time. If the former is true, the economic depreciation should be reflected in an aging adjustment to the rental rate. The Bureau of Labor Statistics began applying an aging adjustment to the rental rate in 1988.[10] The regression methodology adopted by the BLS is based on work by Randolph (1988) that attempts to differentiate depreciation due to physical deterioration due to aging or inadequate maintenance from obsolescence due to advances in technology embodied in new construction. In practice, Randolph's methodology detected little in the way of vintage effects. Our methodology assumes that all depreciation is due to inadequate maintenance or aging.

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about 0.5 percentage point annually. This problem was corrected in 1995.

[10]In January 1988, the BLS introduced an aging adjustment that had the effect of raising the housing services inflation rate about 0.3 percentage point annually.

A potentially more serious problem is that rental homes and owner-occupied homes represent different market segments, and movements in prices of the two segments may diverge (Price Statistics Review Committee, 1961). With respect to the effect of a unit's age on price, for example, we show that unlike rental properties, owner-occupied housing values are not strongly related to age. This implies that homeowners maintain their properties more fully and upgrade them to compensate for obsolescence. Thus, increases in reported rents may overstate the rate of increase of the implied rental rates of owner-occupied housing because the rental increases are for properties that are depreciating faster than owner-occupied housing.

III. Hedonic Approach to Measuring Housing Services Inflation

Housing is essentially a bundle of goods: kitchen, bathrooms, bedrooms, etc. There is a vast literature on hedonic techniques applied to the housing market to estimate the underlying prices of various elements of the housing bundle (see Sheppard (1998) for a review and references therein for reviews of the empirical literature). There is almost as large a literature devoted to constructing indices of house price appreciation, and many of these papers use hedonic techniques to control for changes in house quality over time (see Malpezzi, Chun and Green (1998) for a recent example). Surprisingly, there is virtually no literature using hedonic methods to construct indices of price changes of housing services.[11]

Estimating changes in the price of housing service flows requires estimating the market

[11]House price appreciation indexes are not indexes of the change in the flow of housing services for owner-occupied houses because they do not distinguish between gains in the value of a capital asset and changes in the underlying value of the service. In other words, house price appreciation indexes do not control for changes in the capitalization rate.

rent of constant-quality rental housing, the market price of constant-quality owner-occupied housing, and the capitalization rate of owner-occupied housing. Consumers make a tenure choice based on individual optimization, and the capitalization rate makes the marginal consumer indifferent between renting and owning. Along the margin of choice, inflation rates should be approximately equal, but elsewhere the inflation rates are free to diverge. Using hedonic techniques, we can identify the capitalization rate that yields renter and owner indifference while statistically controlling for differences in housing unit traits.

To construct measures of changes in the price and quantity of constant-quality housing services, we estimate the market prices of the component housing traits, and using the estimates of the stock of these traits, we can estimate the change in the value of an average constant-quality house. For owner-occupied housing, a typical hedonic regression takes the form:[12]

(1) $$\text{Ln } V_{it} = \beta_t X_{it} + e_{it}$$

where: V_{it} is the value of house I in time t;

X_i is a k element row vector of housing traits of house I; and

β_t is a vector of the estimated percent contribution to value of individual traits.

The stream of housing services, which implicitly is equal to the rent, R_{it}, depends on the cost of housing V_{it} and a capitalization rate, C_t, as follows:

$$R_{it} = C_t V_{it.}$$

Thus equation (1) can be written as $\ln(R_{it} / C_t) = \beta_t X_{it} + e_{it}$ or:

(1') $$\ln(R_{it}) = \beta_t X_{it} + \ln(C_t) + e_{it}$$

[12]There is a large literature on the appropriate choice of functional form for the hedonic price function (see Linneman 1980, for example), but the simple log-linear form generally performs very well.

A corresponding hedonic regression for rent is given by:

(2) $$Ln(R_{jt}) = \gamma_t X_{jt} + u_{jt}$$

where R_{jt} is the rental rate of unit j in time t and

γ_t is a vector of the estimated percent of rent associated with individual traits. Unlike the owner-occupied units, the capitalization rate does not appear in the equation for renter-occupied units, since the service flow is observed directly. Note, however, that in the semi-log functional form, if owners and renters value housing traits similarly, $\beta_t = \gamma_t$, the owner and renter hedonic equations differ only by a constant, $\ln(C_t)$.

If C_t can be estimated, then using estimates of the parameters of (1), we can construct indexes of the price of owner-occupied housing services as follows: Let $W_{it} = Z_{it}^{-1}$ where Z_{it} is the sampling probability of house i. Also, let X_{ot} be an I by k matrix whose rows consists of values of each of the housing traits for the i^{th} house of the I owner-occupied houses in the sample; and W_{ot} be a 1 by I vector of weights that blows the sample up to the universe. Then C_t $W_{ot} \exp(B_t X_{ot})$ is a measure of the nominal value of rental services in period t in dollars of period t. Using the matrix of characteristics of homes in period t+n and using base year trait prices, we can determine the real output of the services in period t+n in prices of period t by C_t W_{ot+n} $\exp(B_t X_{ot+n})$. A Laspeyres quantity index of housing services is then $W_{ot+n} \exp(B_t X_{ot+n})/W_{ot}$ $\exp(B_t X_{ot})$, as the capitalization terms cancel out. A Paasche quantity index of housing services is then $W_{ot+n} \exp(B_{t+n} X_{o\,t+n})/W_{ot} \exp(B_{t+n} X_{o\,t})$. We can construct a Fisher Ideal index of housing services quantities as: $((W_{ot+n} \exp(B_t X_{ot+n})/W_{ot} \exp(B_t X_{ot}))(W_{ot+n} \exp(B_{t+n} X_{o\,t+n})/W_{ot} \exp(B_{t+n} X_{o\,t})))^{1/2}$.

Holding the matrix of characteristics of homes constant, we can determine the price of the

same bundle of services in period t+n by $C_{t+n}\, W_{ot}\, \exp(B_{t+n}X_{ot})$. A Laspeyres price index of owner occupied housing services is $W_{ot}\exp(B_{t+n}X_{ot})C_{t+n}/W_{ot}\exp(B_tX_{ot})C_t$. A Paasche price index of owner occupied housing services is $W_{ot+n}\exp(B_{t+n}X_{o\,t+n})C_{t+n}/W_{ot+n}\exp(B_tX_{o\,t+n})C_t$, and we can construct a Fisher Ideal index of owner occupied housing service prices as:

$((W_{ot}\exp(B_{t+n}X_{ot})C_{t+n}/W_{ot}\exp(B_tX_{ot})C_t))(W_{ot+n}\exp(B_{t+n}X_{o\,t+n})C_{t+n}/W_{ot+n}\exp(B_tX_{o\,t+n})C_t))^{1/2}$.

If we are analyzing changes in owner-occupied housing only and if $C_t = C$ for all t, the capitalization rate drops out of the index and the owner-occupied house price index is a valid index for cost of housing services. The capitalization rate is, however, likely to change over time because it is a function of the user-cost of capital, which in turn depends on taxes, income tax advantages of housing, mortgage rates, depreciation, rent and zoning regulations, and the expected future value of residential properties. Unfortunately, the capitalization rate C_t is a scale parameter and cannot be estimated from a sample of owner-occupied units alone.

If we are constructing an index for the total flow of housing services, it is important that we have an estimate of the capitalization rate for two reasons. First, the capitalization rate, as shown above, affects the measured inflation index of owner-occupied housing. Second, the capitalization rate, in part, determines the size of the service flow of owner-occupied housing relative to that of renter-occupied housing and other goods and hence its weight in the CPI. This becomes clear if we note that the total flow of housing services in a given year from rental housing is $\exp(\gamma_t X_{rt})$ where X_{rt} is the quantity of rental traits and is defined analogously to X_{ot}; define W_{rt} analogously. Thus the total flow of housing services is the sum of the flow to owners and renters: $C_t\, W_{ot}\exp(\beta_t X_{ot}) + W_{rt}\exp(\gamma_t X_{rt})$. Note that indexes of price changes for the same bundles of housing based on this sum will depend on the capitalization rate, even if the

capitalization rate is unchanged between the two periods. The Laspeyres price index of total housing services, for example, is given by $(W_{rt} \exp(\gamma_{t+n} X_{rt}) + W_{ot} C_{t+n} \exp(\beta_{t+n} X_{ot})) / (W_{rt} \exp(\gamma_t X_{rt}) + W_{ot} C_t \exp(\beta_t X_{ot}))$.

If we assume that $\beta_t = \gamma_t$, we can combine the owner and rental sample to estimate the capitalization rate as well as trait prices.[13] We use owner-occupied and rental dummies to formulate the estimating equation.

$D_o = 1$ if unit is owner occupied and 0 if it is rented.

$D_r = 1$ if unit is rented and 0 if it is owner-occupied.

(3) $$\ln (C_t V_{it}) D_o + \ln(R_{jt}) D_r = \beta_t X_{lt} + e_{lt}$$

Where:

X_{lt} is matrix of characteristics of homes of owners and renters;

l runs from 1 to I+J, the total number of housing units;

(3') $$\ln (V_{it}) D_o + \ln (R_{jt}) D_r = -\ln (C_t) D_o + \beta_t X_{lt} + e_{lt}$$

Since V_{it} is zero whenever D_o is zero and R_{it} is zero whenever D_r is zero, we can rewrite 3' as

(3'') $$\ln (V_{it} + R_{jt}) = \alpha D_o + \beta_t X_{lt} + e_{lt}$$

[13]It is not necessary to assume that all components of β and γ are the same in order to obtain this identification. See Linneman and Voith (1991).

The capitalization rate $C_t = \exp(-\alpha)$ can be estimated straightforwardly in the regression (3'')[14] Estimating (3'') separately for two time periods allows the calculation of price indexes for the total flows of housing services. In the pages that follow, we present hedonic-based estimates of price indexes for housing services based on data from the 1985 and 1993 national cross-sections of the American Housing Survey and compare them to the BLS and other measures of the change in price of housing services.

IV. The American Housing Survey Data

The American Housing Survey national cross-sections are useful for evaluating changes in the price and quantity of U.S. housing services for two reasons. First, they have data on housing attributes, prices, and rental rates that can be used to estimate hedonic equations and capitalization rates. Second, each cross-sectional sample has associated weights that can be used to expand the sample to the housing universe. These weights allow the calculation of the total flow of housing services, given a set of estimated trait prices and capitalization rates. In addition, the data can be used to construct simpler measures of changes in the price and quantity of housing service flows, such as price per square foot or price per room of housing, that may provide useful baseline comparisons.

There are, however, a number of problems with the AHS data, one of which is missing values. Although every observation in the AHS sample has an associated weight that can be used to expand the sample to national totals, some observations have missing values for the key

[14]Linneman and Voith (1991) investigate the appropriateness of pooling owners and renters.

variables for which we wish to impute national totals, including rent, house value, and unit square footage. Other observations had missing values for particular housing traits that were used in hedonic regressions. However, one measure of housing services, number of rooms, does not have any missing values.

Truncation presents another problem in the AHS data. Rent, value, and unit square footage all have upper bounds on their values, and these upper bounds change across years. It is possible to impute values for both missing and truncated variables; the procedures are detailed in the data appendix. The variable with the most serious missing value and truncation problems was square footage. To avoid the problems with the square foot variable, we have focused on number of rooms rather than square footage as our measure of housing size and as a simple measure of housing services.[15] Table 2 displays the sample means and standard deviations of the variables used in the analysis for the 1985 and 1993 cross-sections. The data shown are prior to any imputations and correspond to the data used in the estimation of the hedonic equations.

Changes in Simple Measures of Housing Prices and Quantities

Using the AHS sample weights and the data on rent, value, and number of rooms, we computed simple estimates of total nominal change in the value of housing services, the change in total number of rooms of housing, and the value per room. The computations were made separately for owner- and renter-occupied housing. The change in number of rooms is a rough estimate of the change in the amount of housing services while the change in the value per room

[15]We have also done the analysis using square footage as our primary measure of housing size and the results are qualitatively similar. In fact, the hedonic estimates are virtually identical.

is a rough measure of the change in the value of nominal housing services resulting from the change in price of housing.[16]

Tables 3A and 3B show the total nominal value of housing services (row 3), total number of rooms (row 2), and value per room (row 1) for both cross-sections as well as the percent change in each measure from 1985-93. Table 3A shows the figures for owner-occupied units, and Table 3B shows the same information for renter-occupied units. Thus, the third column displays the estimates of changes in total nominal value, changes in real housing services, and changes in the price of housing services on the assumption that number of rooms is a measure of housing services and that the capitalization rate for owner-occupied housing did not change between 1985 and 1993. The fourth column shows the official BLS data for CPI for tenants and for owners. Based on the AHS data, the nominal value of owner-occupied housing increased considerably faster (60.7 percent) than the value of renter-occupied services (45.1 percent). The difference in growth in nominal values was roughly split between differences in growth in quantity and differences in growth in prices. The number of rooms in owner-occupied housing increased 11.2 percent while the number of rooms in renter-occupied housing increased only 5.7 percent. The rates of price change per room were higher for owner-occupied housing units, increasing 44.5 percent compared with 37.2 percent for renter-occupied units. Both of these simple measures are slightly higher than the corresponding changes in the CPI of 41.8 percent for owner-occupied housing and 34.4 for renter-occupied units. Both our simple measures and the CPI measures suggest that owner-occupied housing prices increased substantially faster than

[16]These are, of course, imperfect measures because the size and quality of rooms, as well as other attributes of the housing stock, can change over time.

renter-occupied prices.

V. Hedonic Estimates of Changes in the Price and Quantity of Housing Services

Hedonic estimates based on equations 1 and 2 suggest different changes in the prices of housing services. Table 4 presents results for the 1985 cross-section, and Table 5 presents the results for the 1993 cross-section. The estimated coefficients (trait prices) are generally of the expected signs and of reasonable magnitudes. The relative prices of individual traits are generally consistent across time periods; however, there are some important differences in trait prices between owners and renters. In particular, building age has a much larger negative impact for renters than for owners. In addition, the neighborhood variables have larger (in absolute value) and more significant values for owner-occupied units.

Using the estimated trait prices and estimated quantities of the traits, we construct measures of the change in the quantity of housing services keeping prices constant, constant-quality changes in the price of housing services, and the total nominal change in the value of housing services. These estimates are shown in Table 6A for owner-occupied housing and Table 6B for renter-occupied housing. The first column of these tables uses 1985 trait prices and quantities. In the first row of column 2, the estimates use 1985 traits but 1993 trait prices, and thus the change shown in the third column of row 1 is the constant-quality change in price. In the second row of column 2, the constant price change in housing services holds trait prices at their 1985 estimates but uses 1993 trait quantities, and, thus, the third column of the second row represents the change in housing services, holding prices constant. The row labeled total uses 1993 trait prices and quantities, and, thus, the changes in the third row represent the nominal

change in housing services. In column 3, Tables 6A and 6B report the estimates of changes in total nominal value (row 3), changes in real housing services (row 2), and changes in the price of housing services based on 1985 quality (row 1).

Consider, first, the owner-occupied housing. Constant-quality housing prices increased about 31.1 percent. This estimate is considerably less than the estimates based on the price per room (44.5 percent) and the CPI estimate (41.8 percent) shown in columns 3 and 4 of Table 3A. The estimated real increase in owner-occupied housing services was about 20.4, which is considerably larger than the 11.2 percent increase in the number of rooms (Table 3A column 3). Finally, the nominal increase in the owner-occupied housing services is estimated to be 58.1 percent, which is slightly lower, but generally comparable to the 60.7 percent estimate based on nominal house prices (Table 3A column 3).

Turning to renter-occupied housing, constant-quality rental rates increased 40.1 percent, which is slightly greater than the estimates for per room rents in Table 3B (37.2 percent) and considerably higher than the CPI estimate of 34.4 percent (Table 3B column 4). Real rental housing services rose at nearly the same rate (5.3 percent) than rental rooms (5.7 percent). The estimated increases in the nominal value of rental services based on the hedonic method was considerably larger (48.0 percent) than the estimate based on the number of rooms (37.2) percent.

When comparing the owner-occupied and rental markets, the patterns of constant-quality price change are considerably different for the measures based on the hedonic models and the measures based on per room prices or based on the CPI. Constant-quality house price increases estimated by the hedonic method show considerably slower increases in owner-occupied units than in rental units. This stands in stark contrast to the estimates based on the prices per room

and the CPI estimates. According to the estimate of price per room or the CPI, owner-occupied housing prices increased faster than rents. In fact, according to the CPI, the value of owner-occupied units increased 22 percent *faster* than rents, but according to the hedonic method, price of owner-occupied housing increased 22 percent *slower* than rents.

The Overall Changes in the Price and Quantity of Housing Services

The rate of overall change in the price and quantity of housing services depends on what is happening in both the owner-occupied and renter-occupied markets. The weight in a price index of housing services depends not only on the number of units in each market but also on how each unit is valued. The capitalization rate, which converts the stock of owner-occupied housing to a flow of housing services, affects the relative magnitude of the owner to renter market. If capitalization rates are high, a given house value implies a greater rental stream, and thus the overall weight of the owner-occupied market would be greater. Similarly, lower capitalization rates would increase the relative weight of the renter-occupied market.

Table 7 shows overall housing constant-quality price indexes based on our hedonic estimates for alternative capitalization rates prevailing in each period. Along the diagonal, capitalization rates are equal across periods. Because the capitalization rate affects the relative weighting of owner and rental properties in the price index for housing services, the price index falls when the capitalization rate rises as more weight is placed on the owner series, which has lower increases. The effects of weighting are relatively small; the index falls only 0.4 percentage point as the capitalization rate (in both periods) rises from 8 percent to 10 percent.

The off-diagonal elements of Table 7 represent the effects of changing capitalization rates over time as well as the weighting impacts. The effects of changes in capitalization rates over

time are potentially much larger than the effects that operate through the relative weights of owners and renters in the series. A half percentage point change in the capitalization rate, say, from 9 percent in 1985 to 9.5 percent in 1993, increases the measured inflation over the eight-year period from 33.4 percent to 38.9 percent and raises the average annual inflation rate for housing services from 3.7 percent to 4.2 percent.

Table 7 implies that a good measurement of the price changes of housing services, or even the implied value of owner-occupied housing services, demands an accurate measurement of the capitalization rate for the beginning and ending period. By pooling the owners and renters, we can estimate equation (3) for each cross-section to get estimates of the capitalization rate for each period.[17] These estimates are shown in Table 8.

The coefficients on the dummy variable for owner-occupied housing are nearly identical for both cross-sections. The coefficient of 4.905 implies an annual capitalization rate of 8.89 percent in 1985, and the coefficient of 4.907 implies a capitalization rate of 8.87 percent in 1993.[18] Even though these coefficients are precisely estimated, they are not significantly different from one another. This implies that capitalization, except for its small effect on weighting of owner and renter-occupied units, can essentially be ignored for the time period we examine. Using the capitalization rate estimate for 1985 yields an increase in the price for all housing services of 33.4 percent or 3.7 percent annually for the period 1985-93. A 90 percent

[17]Linneman and Voith show that capitalization rates may differ systematically across people, even in a given cross-section as a result of tax and life-cycle considerations. We abstract from these issues here. In addition, pooling owners and renters imposes the restriction that the trait prices are the same across samples, up to the scale of capitalization.

[18]Since our rent data are monthly, the capitalization rate is given by 100*12*(exp(-4.905)).

confidence interval on the capitalization rate goes from 8.73 percent to 9.04 percent for 1985. Housing service prices can rise or fall 1.6 percentage points within this range. That seems a substantial range for year-to-year inflation but does not appear to be such a substantial problem for longer term measures of inflation.

If we were to examine other periods, capitalization rates would likely be very different and, hence, have an important effect on the index of the price of housing services. Capitalization rates for the early 1980s, when mortgage rates were well into double digits, are likely to be very high. For example, Linneman and Voith's estimated capitalization rates based on the 1983 AHS data only two years earlier were over 10.5 percent for the average home owner. Long term interest rates were substantially higher on average from 1985 to 1993 than they have been since then. As a result, 1999 capitalization rates were likely to be significantly lower than the 8.9 percent prevailing in 1985 and 1993.

Conclusion

In this paper we have used standard hedonic techniques to overcome some of the problems of measuring changes in constant-quality housing services. We estimated the hedonic parameters for 1985 and 1993 on the characteristics of rental units. We used these parameters to calculate market rents for a constant-quality house in the two years and the corresponding increase in rents. According to our hedonic estimates, the cost of rental housing rose 40.1 percent while the BLS estimated that it rose 34.4 percent. These differences may reflect differences in the methodology for accounting for vintage effects.

Hedonic methods are even more useful for estimating changes in the cost of housing

services for homeowners. Even though the BLS attempts to construct a sample of rental units that are similar to owner-occupied houses, we have listed several reasons why this sample may not yield a good estimate of the rental equivalent of owner-occupied housing. Using hedonic methods we can estimate the market value (rather than the rental equivalent) of a constant-quality owner-occupied house in two different periods. If the capitalization rate remains the same in both periods, the change in the value of the house can be translated directly into the change in the user cost of capital for the homeowner. Using data on rental and owner-occupied houses, we estimated that the capitalization rate remained essentially unchanged between 1985 and 1993. Under these circumstances, our hedonic estimates imply a 31.1 percent increase in the cost of housing services for homeowners. This is considerably less than the 41.8 percent increase estimated by the BLS. Given our best estimate of the capitalization rate, we estimate that the overall price increase of housing services for the period was 33.4 percent, an average annual rate of 3.7 percent, which is lower than the CPI estimate of 40.0 percent, an average annual rate of 4.3 percent. Our estimate is very close to Moulton's (32.9 percent), which corrects the CPI for aging bias before 1988, misreporting, and computational errors in the owner's equivalent rent calculation before 1995.

Estimates of changes in the capitalization rate are crucial for estimating changes in the cost of housing services for two reasons. First, an increase in the capitalization rate raises the cost of housing services for homeowners even if the market value of constant-quality houses does not change. Second, an estimate of the capitalization rate is necessary to determine the total flow of housing services from the stock of owner-occupied houses. The combined flow of services to renters and homeowners constitutes the total flow of housing services. And the proportions of

each will determine how much rental increases and increases in the user cost of owner-occupied housing affect changes in the total cost of housing services.

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Data Appendix

Although every observation in the AHS sample has an associated weight that can be used to expand the sample to national totals, some observations have missing values for the key variables for which we wish to impute national totals, including rent, house value, and square footage. Less crucially, other observations had missing values for particular housing traits that were used in hedonic regressions. With respect to the missing values for rent, house value, and unit square footage, we used the following simple imputation method. Since the number of rooms was available for all units, we computed the sample average ratios of rent, value, and unit square footage to number of rooms and used this ratio in conjunction with the observed number of rooms for the observation with the missing variable to impute the missing value. The imputation was done separately for owner-occupied and renter-occupied units. Table A1 summarizes the number of observations requiring imputations. The missing value problem is far more serious for rental properties, since about two-thirds of the observations required imputation of rent or unit square footage. The great majority of the units without rent data were rent subsidized units; units missing square footage data displayed no such pattern.

In addition to missing values for rent, value, and square footage, observations had missing values on variables used in the hedonic estimations. If the missing values are not systematically correlated with the regressors, there are no special difficulties estimating the hedonic price function. However, to aggregate to the total real value of housing services, we need to have an estimate of the total stock of each trait for both cross-sections. We therefore imputed missing values.

Truncation presents another problem in the AHS data. Rent, value, and unit square footage all have upper bounds on their values. Unfortunately, these upper bounds change across cross-

sections. Truncation is most problematic for unit square footage, whose upper bound was decreased from 5000 square feet in 1985 to 4000 square feet in 1993, even while the median square footage of units in the sample increased over the period. As shown in Table A2, 1019 of the 1985 cross-section observations fell into the greater-than-5000-square-foot category and 1408 of the 1993 observations fell into the greater-than-4000 category. To address the changing truncation levels, we recoded the observations in the 1985 cross-section such that all observations with value greater than 4000 were simply given a value of 4000, as in the 1993 sample.

The truncation limits for both rent and value are less of a problem because the limits were increased from 1985-93. The maximum rent and value increased from $750 per month and $250,000 respectively in 1985 to $999 and $349,999 in 1993. At these levels, the magnitude of the truncation problem was much smaller. As is shown in Table A2, 302 observations had reported rents greater than $750 in 1985 and 478 exceeded $999 in 1993. Similarly for value, 441 exceeded the $250,000 1985 limit and 871 exceeded the 1993 limit. The same procedure used for the unit square footage could not be employed in the case of rent and value, as this would only exacerbate the truncation problem. In the analysis that follows, the observations at the truncation level were simply assumed to have the truncation levels for rent and value.

Table 1

U.S. Bureau of Labor Statistics Consumer Price Indexes for Housing Services
(All Urban Consumers)

	Renters' Costs for Shelter: Rent, Residential	Homeowners' Cost for Shelter: Owners' Equivalent Rent	Total: Housing Services, Shelter: Rent and Rent Equivalent Components
1985	111.8	113.2	112.9
1993	150.3	160.5	158.0
Percent increase	34.4	41.8	40.0

Table 2
Sample Means and Standard Deviations

	1985		1993	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Rent[1]	335.35	160.76	469.28	216.14
Value[2]	71685.49	52292.63	105665.40	79751.10
Owner-occupied dummy	0.72	0.45	0.71	0.45
Multi-unit dummy	0.22	0.42	0.22	0.42
Building age	30.07	20.45	34.56	21.91
Number of bathrooms	1.42	0.53	1.52	0.56
Public sewer dummy	0.75	0.44	0.76	0.43
Central air dummy	0.35	0.48	0.46	0.50
Holes in floor dummy	0.01	0.12	0.01	0.11
Mice dummy	0.04	0.20	0.02	0.15
Number of rooms	5.68	1.80	5.77	1.82
Garage dummy	0.60	0.49	0.63	0.48
Nonresidential use dummy	0.02	0.14	0.02	0.12
Crime dummy	0.04	0.20	0.07	0.25
Noise dummy	0.07	0.26	0.08	0.27
Trash dummy	0.07	0.26	0.05	0.23
Satisfaction with unit	8.27	1.90	8.35	1.72
Satis. with neighborhood	8.19	2.08	8.13	1.99
Midwest dummy	0.26	0.44	0.25	0.43
South dummy	0.34	0.47	0.34	0.47
West dummy	0.19	0.39	0.21	0.40

[1]The number of rental units for 1985 is 9,175. The number of rental units for 1993 is 10,326

[2]The number of owner-occupied units is 23,769 for 1985 and 25,762 for 1993. Summing the owner-occupied and renter-occupied units results in a total of 32,944 observations for 1985 and 36,088 observations for 1993.

Table 3A
Owner-occupied Units

Variable	1985	1993	% Change	% Change in CPI
Value/Rooms (thousands)	11.60	16.80	44.50	41.8
Rooms (millions)	347.11	386.11	11.24	
Value (trillions)	4.03	6.47	60.73	

Table 3B
Renter-occupied Units

Variable	1985	1993	% Change	% Change in CPI
Rent/Rooms	77.12	105.81	37.20	34.4
Rooms (millions)	139.50	147.51	5.74	
Rent (billions)	10.76	15.61	45.08	

Table 4
1985 Estimations

	Owner-occupied[1]		Renter-occupied[2]	
	Coef	S.E.	Coef	S.E.
Intercept	8.943*	0.035	5.078*	0.038
Multi-unit dummy	0.196*	0.019	0.198*	0.012
Building age (x100)	-0.065	0.025	-0.569	0.027
Number of bathrooms	0.330*	0.011	0.332*	0.015
Public sewer dummy	0.099*	0.010	0.202*	0.016
Central air dummy	0.164*	0.011	0.168*	0.013
Holes in floor dummy	-0.300*	0.049	-0.183*	0.030
Mice dummy	-0.141*	0.025	-0.094*	0.020
Number of rooms	0.115*	0.003	0.050*	0.004
Garage dummy	0.423*	0.010	0.152*	0.011
Nonresidential use dummy	0.039	0.031	0.036	0.035
Crime dummy	0.003	0.026	0.087*	0.020
Noise dummy	-0.001	0.019	0.007	0.015
Trash dummy	-0.056*	0.017	0.029	0.019
Satisfaction with unit	0.054*	0.003	0.000	0.003
Satis. with neighborhood	0.012*	0.003	0.000	0.003
Midwest dummy	-0.454*	0.013	-0.335*	0.015
South dummy	-0.379*	0.013	-0.408*	0.015
West dummy	0.019	0.015	-0.080*	0.016
Adjusted R^2	0.387		0.369	
Number of observations	23,769		9,175	

[1]Dependent variable is the log of price.

[2]Dependent variable is the log of rent.

* Denotes significance at the 5% level

Table 5
1993 Estimations

	Owner-occupied[1]		Renter-occupied[2]	
	Coef	S.E.	Coef	S.E.
Intercept	9.028*	0.039	5.382*	0.037
Multi-unit dummy	0.308*	0.024	0.176*	0.011
Building age (x100)	0.108*	0.025	-0.314*	0.024
Number of bathrooms	0.313*	0.010	0.292*	0.013
Public sewer dummy	0.098*	0.010	0.226*	0.016
Central air dummy	0.153*	0.011	0.149*	0.012
Holes in floor dummy	-0.342*	0.054	-0.060	0.031
Mice dummy	-0.102*	0.036	-0.024	0.023
Number of rooms	0.126*	0.003	0.049*	0.004
Garage dummy	0.396*	0.011	0.119*	0.011
Nonresidential use dummy	0.037	0.037	0.005	0.035
Crime dummy	0.034	0.023	0.049*	0.015
Noise dummy	0.004	0.020	0.040*	0.014
Trash dummy	-0.107*	0.021	-0.046	0.019
Satisfaction with unit	0.070*	0.003	0.006	0.003
Satis. with neighborhood	0.018*	0.003	0.002	0.002
Midwest dummy	-0.538*	0.014	-0.404*	0.014
South dummy	-0.530*	0.014	-0.507*	0.014
West dummy	-0.008	0.015	-0.133*	0.015
Adjusted R^2	0.392		0.334	
Number of observations	25,762		10,326	

[1]Dependent variable is the log of price.

[2]Dependent variable is the log of rent.

* Denotes significance at the 5% level

Table 6A
Owner-occupied Units

Variable	1985	1993	% Change
Constant traits (trillions)	3.43	4.50	31.06
Constant prices (trillions)	3.43	4.14	20.44
Total (trillions)	3.43	5.43	58.10

Table 6B
Renter-occupied Units

Variable	1985	1993	% Change
Constant traits (billions)	8.69	12.17	40.06
Constant prices (billions)	8.69	9.16	5.34
Total (billions)	8.69	12.87	48.03

Table 7

Alternative Capitalization Rates and Housing Services Price Indexes: Eight Year Price Increases					
1985 Capitalization Rate	1993 Capitalization Rate				
	8.0 %	8.5 %	9.0 %	9.5 %	10.0 %
	Percentage Increase in Housing Services Inflation, All Units, 1985-93				
8.0 %	33.6%	39.6%	45.7%	51.7%	57.8%
8.5 %	27.7%	33.5%	39.2%	45.0%	50.8%
9.0 %	22.3%	27.8%	33.4%	38.9%	44.4%
9.5 %	17.3%	22.6%	28.0%	33.3%	38.6%
10.0 %	12.8%	17.9%	23.0%	28.1%	33.2%

Table 8
Pooling Owners and Renters: Estimating Capitalization Rates

	1985		1993	
	Coef	S.E.	Coef	S.E.
Intercept	4.378*	0.027	4.539*	0.027
Owner-occupied dummy	4.905*	0.011	4.907*	0.010
Multi-unit dummy	0.274*	0.012	0.315*	0.011
Building age(x100)	-0.216*	0.020	0.002	0.019
Number of bathrooms	0.343*	0.009	0.326*	0.008
Public sewer dummy	0.124*	0.009	0.127*	0.009
Central air dummy	0.172*	0.009	0.159*	0.008
Holes in floor dummy	-0.200*	0.031	-0.165*	0.033
Mice dummy	-0.105*	0.018	-0.046*	0.024
Number of rooms	0.103*	0.003	0.112*	0.003
Garage dummy	0.344*	0.008	0.306*	0.008
Nonresidential use dummy	0.026	0.025	0.021	0.028
Crime dummy	0.045*	0.018	0.048*	0.015
Noise dummy	0.009	0.014	0.020	0.013
Trash dummy	-0.048*	0.014	-0.080*	0.015
Satisfaction with unit	0.034*	0.002	0.044*	0.002
Satis. with neighborhood	0.008*	0.002	0.012*	0.002
Midwest dummy	-0.418*	0.011	-0.503*	0.011
South dummy	-0.391*	0.011	-0.531*	0.011
West dummy	-0.022*	0.012	-0.061*	0.011
Adjusted R^2	0.935		0.933	
Number of observations	32944		36088	

* Denotes significance at the 5% level

Table A1

Imputed values:	1985 Renter (9,175 observations)	1985 Owner (23,769 observations)	1993 Renter (10,326 observations)	1993 Owner (25,762 observations)
UNITSF	4142	1155	4667	2289
RENT	3804	-	3822	-
VALUE	-	33	-	55

Table A2

	1985 Upper Bound	1985 Category Definition	1985 # of obs. in category	1993 Upper Bound	1993 Category Definition	1993 # of obs. in category
UNITSF	5001	>5000	1019	4038	>4000	1408
RENT	751	>750	302	1000	>999	478
VALUE	250001	>250000	441	350000	>349999	871