Chapter 4

HEDONIC ESTIMATES OF THE COST OF HOUSING SERVICES: RENTAL AND OWNER OCCUPIED UNITS

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1. Introduction

Housing services account for a seventh of U.S. personal consumption expenditures. For rental units, housing costs are directly observed in the form of market rents. For owner occupied housing (OOH) services, many economists feel that the preferred measure of housing costs is the user cost of capital.[2] Since 1983, the U.S. Bureau of Labor Statistics (BLS) has measured the inflation rate for rental units similar to owner occupied units and has used this as a proxy for the inflation rate for the OOH service flow: the rental equivalent way of measuring the user cost of capital for OOH.[3]

In this study, we compare the BLS estimates of increases in rents and owner occupied housing costs to hedonic regression based estimates based on data from the American Housing Survey (AHS). We argue that our hedonic regression based method represents an alternative to the current BLS method. The method is applied to renter and owner occupied housing over the period from 1985 to 1999. Our empirical results suggest that for the period of 1985-1999 in the United States, the CPI component for housing may have slightly underestimated rental increases and significantly overestimated increases in housing costs for homeowners.

Section 2 outlines the BLS rental equivalent method. Section 3 presents our hedonic method. Section 4 describes the data used. Section 5 compares our measures of owner occupied housing services inflation with those of the BLS. Section 6 concludes.

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[2] For more on user costs, see for example Diewert (1974, 2003). See also Diewert and Nakamura (2009).

[3] See Smith, Rosen and Fallis (1988) on implicit rent as a measure of the user cost of capital for the marginal homeowner.

Crone, T.M., L.I. Nakamura and R.P. Voith (2009), "Hedonic Estimates of the Cost of Housing Services: Rental and Owner Occupied Units," chapter 4, pp. 51- 68 in
W.E. Diewert, B.M. Balk, D. Fixler, K.J. Fox and A.O. Nakamura (2009),
***PRICE AND PRODUCTIVITY MEASUREMENT: Volume 1 -- Housing.* Trafford Press.**
Also available as a free e-publication at www.vancouvervolumes.com and www.indexmeasures.com.

2. The BLS Methods for Measuring Inflation in Housing Services

Households derive a service flow from the dwellings they inhabit. In exchange for this service flow, renters pay an explicit rent and owners pay an implicit "equivalent" rent. What we have data on are rents in the first case and dwelling prices in the second.

Beginning in 1978, the BLS estimated rental increases by sampling rental units on a six month rotation. By 1999, the BLS was collecting rent data for about 25,000 units. Rent data are transactions prices, as reported in tenant surveys and interviews rather than posted prices. Evaluating measured rental inflation by survey is complicated by at least three factors: (1) the quality of a given apartment or house can change over time because of imperfect maintenance or through improvements made by the landlord or tenants;[4] (2) tenants' reports of changes in rents may be inaccurate;[5] and (3) tenants move and vacant apartments, where rents are not recorded, may have different inflation rates.[6] The methods used by the BLS to measure rental inflation for individual units have evolved over time to correct for various measurement problems.[7]

Prior to 1983, the BLS arrived at estimates of homeowner expenses by making estimates of individual cost components including mortgage interest costs, home purchase prices, insurance costs, and so forth. In 1983, the BLS adopted the concept of owners' equivalent rent for the CPI (Gillingham and Lane, 1982). For the period of 1983 to 1986, owners' equivalent rent was calculated by reweighting the rent sample to better represent owner occupied units, since the typical owner occupied housing unit has many characteristics that differ from a typical rental unit. For example, owner occupied units are predominantly single-family detached units, while rental units are predominantly in multiple unit buildings.

In January 1987, the BLS changed methodology again and began imputing owners' equivalent rent to a sample of owner occupied units by matching each one to a number of rental units in the same neighborhood and with the same structural attributes. Unfortunately, the rental units to which the owner occupied units were matched were aggregated using the Sauerbeck formula, a formula that was shown to cause a systematic overstatement of inflation (Armknecht

[4] The quality issue is complicated further by vintage effects or unmeasured quality differences that are proxied by the age of the unit. All vintage effects are not necessarily negatively related to age; e.g., older units may be located closer to the center of a metro area or surviving older units may represent the highest quality units built in their time (see Randolph, 1988a and 1988b).

[5] When the new formula for estimating changes in rents was introduced in 1978, the tenant was asked what the current month's rent was and what the previous month's rent had been. Two changes -- the current month change and the six-month change -- were then used to estimate the current month change in rent. Research by the BLS found that the reported one-month changes tended to underestimate rental increases. One reason for the underestimation 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 reports of one-month changes by tenants who had occupied the unit in the previous month tended to be underreported. The recall bias was corrected in 1995. Now the BLS estimates the one-month change by the sixth root of the six-month change. See Crone, Nakamura, and Voith (2008).

[6] 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).

[7] Note that the BLS does not attempt to make the CPI a consistently measured series; i.e., changes in methodology are not retroactively applied to the series. Stewart and Reed (1999) discuss this issue and construct a version of the CPI that is intended to be consistently measured from 1978 on. For a discussion of the issues associated with the BLS methodology for collecting rental data, see Crone, Nakamura, and Voith (2008).

et al., 1995). This overstatement is estimated by the BLS to have been about half a percentage point annually. A correction for this problem was implemented in 1995. However, difficulties were encountered in finding rental units in neighborhoods in which homes are predominantly owner occupied.[8] Thus the BLS returned in 1998 to the method used between 1983 and 1986 of reweighting rental units to obtain owners' equivalent rent.

The main concerns that have been raised 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. The issue of maintaining constant quality illustrates these concerns. The CPI is meant to reflect *pure* inflation; that is, it is meant to reflect the change in rent or owner occupied housing costs holding the quality of the unit constant. It is an established fact for rental properties that the rent charged is negatively related to the age of the housing unit. This economic depreciation can be interpreted in either or both of two ways: rental properties physically deteriorate over time as a result of imperfect maintenance, and embodied technological progress makes existing rental properties increasingly economically obsolete over time. Randolph (1988a and 1988b) estimated that, at the national level, rental units depreciate between 0.3 percent and 0.4 percent per year. In 1988, the BLS began applying an aging adjustment to the rental index. In contrast, homeowners are thought to maintain their properties more fully and upgrade them more frequently to compensate for obsolescence. Thus, increases in reported rents adjusted for depreciation from a sample of rental units may overstate the rate of increase of the *implied* rental rates for owner occupied housing because rental properties depreciate faster than owner occupied housing.

3. The Hedonic Approach to Measuring Inflation in Housing Services

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.[9] There is almost as large a literature devoted to constructing indexes of house price appreciation, and many of these papers use hedonic techniques to control for changes in house quality over time.[10] Surprisingly, there is a dearth of studies using hedonic methods to construct indexes of price changes for housing services. House price appreciation indexes are not indexes of the change in the price of the flow of housing services for owner occupied houses because they do not distinguish between gains in the value of the capital asset and changes in the underlying value of the service flow. In other words, house price appreciation indexes do not control for changes in the capitalization rate.

Estimating changes in the price of housing service flows requires estimating the market rent of constant quality rental housing, the market price of constant quality owner occupied

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[8] In general, the market for these units is relatively thin, so that the observed rents may not be good proxies for the implicit value of the housing service flows for owner occupied units. Also, the rental units that have characteristics most like owner occupied dwellings are often temporary rentals; that is, they are in the rental sample for only short time periods. The rent for such units may be unusually high or low depending on the circumstances under which they are temporarily in the rental market. A different sort of problem is that rental units in general are often subject to long-term contracts or price regulation.

[9] See Sheppard (1999) for a review and references to the empirical literature.

[10] See Malpezzi, Chun, and Green (1998), for example. Further discussion of this issue, alternative empirical approaches, and references can also be found in Diewert and Nakamura (2009).

housing, and the capitalization rate of owner occupied housing. Consumers presumably make tenure choices based on individual optimization, and the capitalization rate makes the marginal consumer indifferent between renting and owning. Using hedonic techniques, we can identify the capitalization rate that yields renter and owner indifference while statistically controlling for differences in housing unit traits.

In this paper, we develop separate price indexes for rental and owner occupied units using hedonic methods and a data set that contains both rental and owner occupied units. We estimate capitalization rates and then compute alternative estimates of the rate of inflation of housing services. These alternative estimates are compared with measures of housing inflation from the CPI to help assess possible bias problems in the CPI measures.

The basic procedure is as follows. We estimate hedonic prices for each trait in a bundle of traits providing housing services (bathrooms, garage, etc.) and construct separate constant quality price indexes for rental and owner occupied housing. We estimate a capitalization rate for owner occupied housing that yields an estimate of the value of the service flow from owner occupied housing.[11] Implied capitalization rates are important for measuring inflation in housing because changes in capitalization rates result in changes in the user cost of capital and hence in the inflation rate for owner occupied housing services. Increases in capitalization rates will increase the measured rate of inflation for 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 one or two year intervals, it is quite possible for capitalization rates to change significantly over longer periods of time. Indeed, over the 1985-1999 period, we find that the capitalization rates of owner occupied housing ranged from 8.1 percent to 9.0 percent.

To construct measures of change in the price and the quantity of constant quality housing services, we estimate the market prices of the component housing traits. Then, using the estimates of the quantities of these traits, we 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) $$\ln V_{it} = \beta_t X_{it} + e_{it} \quad \text{for} \quad i = 1,\ldots,I .$$

V_{it} is the value for house i in period time t, X_i is a K element row vector of traits of house i, and β_t is a vector of the estimated percentage contributions to the house value of the housing traits.

The stream of housing services that implicitly is equal to the rent, R_{it}, is hypothesized to depend on the value of housing, V_{it}, and a capitalization rate, C_t, in the following manner: $R_{it} = C_t V_{it}$. Thus equation (1) can be rewritten as $\ln(R_{it} / C_t) = \beta_t X_{it} + e_{it}$, or as

(2) $$\ln(R_{it}) = \beta_t X_{it} + \ln(C_t) + e_{it} \quad \text{for} \quad i = 1,\ldots,I .$$

A corresponding hedonic regression for the rent for rental units is given by:

[11] Linneman (1980), Linneman and Voith (1991), and Crone, Nakamura, and Voith (2000) develop these methods.

[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 semi log form generally performs well.

(3) $\ln(R_{jt}) = \gamma_t X_{jt} + u_{jt}$ for $j = 1,\ldots,J$,

where R_{jt} is the rent for unit j in time t, X_j is a K element row vector of traits of rental unit j, and γ_t is a vector of traits for the individual rental unit. Unlike the case of owner occupied units, the capitalization rate does not appear in the equation for rental units since the price of the service flow is observed directly for rentals. Note, moreover, that in the semi-log functional form, if owners and renters value housing traits similarly, then we will have $\beta_t = \gamma_t$ and the owner and renter hedonic equations will differ only by the constant, $\ln(C_t)$.

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 i^{th} row consists of values for the traits of the i^{th} house in the sample, and let 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, where B_t is an estimator of β_t. Using the matrix of characteristics of homes in period $t+n$ and using base-year trait prices, we can represent the real output of the services in period $t+n$, evaluated in terms of period t prices, by the expression $C_t W_{ot+n} \exp(B_t X_{ot+n})$.

A Laspeyres quantity index of housing services is given by:

(4) $W_{ot+n} \exp(B_t X_{ot+n}) / W_{ot} \exp(B_t X_{ot})$,

since the capitalization terms cancel out. Similarly, a Paasche quantity index of housing services is given by:

(5) $W_{ot+n} \exp(B_{t+n} X_{ot+n}) / W_{ot} \exp(B_{t+n} X_{ot})$.

We can construct a Fisher index of the quantity of housing services as the square root of the product of the Laspeyres and Paasche indexes; e.g., the Fisher index is given by:

(6) $$[\{W_{ot+n} \exp(B_t X_{ot+n}) / W_{ot} \exp(B_t X_{ot})\} \{W_{ot+n} \exp(B_{t+n} X_{ot+n}) / W_{ot} \exp(B_{t+n} X_{ot})\}]^{1/2}.$$

Holding the matrix of characteristics of homes constant, we can determine the price of the same bundle of services in period t+n by $C_{t+n} W_{ot} \exp(B_{t+n} X_{ot})$.

If C_t can be estimated, then we can construct indexes of the price of owner occupied housing services using estimates of the parameters of (2). A Laspeyres price index of owner occupied housing services is given by

(7) $W_{ot} \exp(B_{t+n} X_{ot}) C_{t+n} / W_{ot} \exp(B_t X_{ot}) C_t$.

A Paasche price index of owner occupied housing services is:

(8) $W_{ot+n} \exp(B_{t+n} X_{ot+n}) C_{t+n} / W_{ot+n} \exp(B_t X_{ot+n}) C_t$.

And the Fisher index of the price of owner occupied housing services is given by:

$$(9) \qquad [\{W_{ot}\exp(B_{t+n}X_{ot})C_{t+n} / W_{ot}\exp(B_t X_{ot})C_t\} \{W_{ot+n}\exp(B_{t+n}X_{ot+n})C_{t+n} / W_{ot}\exp(B_t X_{ot+n})\}C_t]^{1/2}.$$

Unfortunately, however, the capitalization rate C_t, which is a scale parameter, cannot be estimated from a sample of owner occupied units alone.[13]

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 is clear if the total flow of housing services in a given year from rental housing is $W_{rt} \cdot \exp(\gamma_t X_{rt})$ where X_{rt} is the quantity of rental traits and is defined analogously to X_{ot} and W_{rt} is defined analogously to W_{ot}. Thus, the total flow of housing services is the sum of the flow to owners and renters:

$$(10) \qquad C_t W_{ot}\exp(\beta_t X_{ot}) + W_{rt}\exp(\gamma_t X_{rt}).$$

Note that changes in the price indexes for the same bundles of housing services based on this sum will depend on the capitalization rate even if the capitalization rate is unchanged between the two periods. For example, the Laspeyres price index of total housing services is given by

$$(11) \qquad \{W_{rt}\exp(\gamma_{r+n}X_{rt}) + W_{ot}C_{t+n}\exp(\beta_{t+n}X_{ot})\} / \{W_{rt}\exp(\gamma_{rt}X_{rt}) + W_{ot}C_t\exp(\beta_t X_{ot})\}.$$

If we assume that $\beta_t = \gamma_t$, we can combine the owner and rental samples to estimate the capitalization rate as well as the trait prices.[14] We use owner occupied and rental dummies to formulate the estimating equation,

$$(12) \qquad \ln(C_t V_{it})D_o + \ln(R_{it})D_r = \beta_t X_{it} + e_{it} \quad \text{for} \quad i = 1, \ldots, I + J,$$

where $D_o = 1$ if the unit is owner occupied and 0 if it is rented, $D_r = 1$ if the unit is rented and 0 if it is owner occupied, and where X_{it} is the matrix of characteristics of the homes of owners and renters. (The subscript i runs from 1 to I+J, the total number of dwelling units including both the owner occupied and the rental ones.) We can rewrite (12) as

$$(13) \qquad \ln(V_{it})D_o + \ln(R_{it})D_r = -\ln(C_t)D_0 + \beta_t X_{it} + e_{it} \quad \text{for} \quad i = 1, \ldots, I + J.$$

Since V_{it} is zero when D_o is zero and R_{it} is zero when D_r is zero, we can rewrite (13) as

$$(14) \qquad \ln(V_{it} + R_{it}) = \alpha_t D_0 + \beta_t X_{it} + e_{it} \quad \text{for} \quad i = 1, \ldots, I + J.$$

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[13] The capitalization rate is also likely to change over time because it is a function of the user cost of capital, which in turn depends on the tax advantages of owner occupied housing, mortgage rates, depreciation, and the expected future value of residential properties.

[14] It is not necessary to assume that all components of β and γ are the same in order to obtain this identification. Linneman (1980) includes some characteristics only for rental units, thus constraining the coefficients on those variables to be zero for owner occupied units. Linneman and Voith (1991) investigate the appropriateness of pooling owners and renters.

The capitalization rate $C_t = \exp(-\alpha_t)$ can be estimated from the regression (14). Estimating (14) separately for two time periods allows the calculation of price indexes for the total flows of owner occupied housing (OOH) services. In the pages that follow, we present hedonic estimates of price indexes for housing services. The data used are from the 1985 to 1999 national cross sections of the American Housing Survey (AHS). We compare the hedonic estimates with the official CPI measures by the BLS of the change in the price of housing services.

4. The American Housing Survey (AHS) Data

Every two years, the U.S. Bureau of the Census conducts a survey of 50,000 to 60,000 rental and owner occupied houses known as the American Housing Survey (AHS). The current panel for the survey dates from 1985, with some units disappearing from the survey every two years and new units being added. We restricted our estimation sample to the years 1985 to 1999 so the estimates would be based on data from the same basic panel.

The cross sections from the national AHS are useful for evaluating changes in the price 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. Theoretically, these weights allow the calculation of the total flow of housing services, given a set of estimated trait prices and capitalization rates.

There are, however, a number of problems with the AHS data, including 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 dependent variables in our hedonic equation (rent and house value). We could not use these observations in the hedonic estimation, but we did use them to calculate the Fisher indexes for rents and owner occupied housing costs as long as they had values for the traits in our regressions. A number of observations in the AHS had missing values for housing traits used in the regressions. These observations could not be used to estimate the trait prices or to calculate implied rents or owner occupied housing costs.

We calculate the change in owner occupied housing (OOH) costs and rents based on the normalized weighted values for the available observations in each year. Each element i of the vector W_{ot} is set equal to $w_{iot} / \sum_{i=1}^{I} w_{iot}$ where I is the number of observations in period t that have no missing values for the housing traits included in the regression equation. We apply an analogous weighting scheme to the rental units to produce a vector W_{rt} of normalized weights. Our annual samples contain approximately 32,000 to 45,000 observations that we can use to estimate the Fisher index of housing costs.

Table A1 in appendix A displays the sample means and standard deviations of the variables used to estimate the Fisher price index for the years of 1985, 1993 and 1999.

Truncation is another problem with the AHS data. The rent and house value data have upper bounds that change over the survey years. Any rent or house value that exceeds the upper bound is coded at the upper limit. In order to avoid systematic mismeasurement of larger and more expensive units, we eliminated from our regression sample any observation that was coded at the upper bound.[15] As a consequence, however, the rent and house value samples are not representative of the underlying housing populations. Since our purpose is to estimate increases in market rents, we also eliminated from our regression sample any rental units where the rent was subsidized.[16] Our regression samples range from approximately 29,000 to 40,000 observations.

Appendix table A2 displays the sample means and standard deviations of the variables used in the regression analysis for the 1985, 1993 and 1999 cross sections.

5. Hedonic Estimates of Rents, the Cost of OOH Services, and Capitalization Rates

The assumption that $\beta_t = \gamma_t$ in equation (12) constrains the choice of traits that we can use in our regression analysis. Kurz and Hoffmann (2009) use owners' estimates of the rental value of their property and market rents for rental properties in West Germany to examine the accuracy of the German CPI for owner occupied housing. In a pooled regression of renters and owners they find that for most of the coefficients on the hedonic characteristics there is no statistically significant difference between the two groups.

The fact that not all the coefficients are statistically the same is not surprising. Linneman (1980) and Linneman and Voith (1991) argue that F-tests that reject the equality of coefficients across samples do not provide conclusive evidence that the samples should not be pooled. They argue that the implicit prices derived from a hedonic price function estimated on either owners or renters alone will be biased for two reasons. First, the owners and renters each are likely to be non-random samples of the population in the housing market. Thus, hedonic price functions estimated on either owners or renters alone will be subject to sample selection bias. Second, because owners and renters typically purchase houses that have different quantities of each trait, non-linearity in the underlying hedonic price function suggests that predicted trait prices outside of the normal range for either owners or renters will not reflect the actions of all participants in the housing market.

Unlike Kurz and Hoffmann's data set, our data set does not include owners' estimates of the rental value of their units but only an estimate of the asset value: the dwelling price. We ran separate owner and renter equations on various sets of variables from the AHS for each of our cross sections to check for similarity in the coefficients for owners and renters. The results of the separate owner and renter equations using the traits that we included in our final estimation are shown in tables A3 and A4 in appendix A.

With one exception, we included in our combined estimates only those traits for which the statistically significant coefficients (at the 5 percent level) had the same sign across years and

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[15] Square footage was also truncated at an upper bound and was missing for a large number of observations. Therefore, we used the number of rooms as our measure of unit size. This variable has many fewer missing values and is not truncated.

[16] We also did not use for our regressions any rental units with recorded rent less than $10 or any homeowner unit with a recorded value less than $1000. We considered such low values the result of miscoding.

for both renters and owners. In some cases, the magnitudes of the coefficients were also close (central air, unit in a multi-unit building, number of bathrooms, and if the unit is in a metropolitan statistical area (MSA)). In other cases, the magnitudes were not close (number of rooms, garage dummy, satisfaction with the neighborhood) even though the signs were the same. Building age was the one exception to our rule for choosing for the combined equation only those traits that had the same sign in the separate renter and owner equations. The coefficient on building age for renters was negative for every year of AHS data from 1985 to 1999. For homeowners the coefficient on building age was positive and significant in five of the regressions, positive and insignificant in one, and negative and insignificant in two of the regressions. Because of the importance of age in the hedonic literature on house values and rents, we included it in our combined equation.

Our estimates of trait prices from the combined sample of rental and owner occupied units are based on equation (14). Table A5 presents the estimates for 1985, 1993, and 1999. We impose the constraint that $\beta_t = \gamma_t$ for all traits. All the significant coefficients on the independent variables except the regional dummies have the same sign across all the years in our sample. The fact that a regional dummy changes sign from one year to the next simply indicates that housing services inflation has been faster or slower in that region relative to other regions.

The coefficient on the owner dummy variable (α) is the basis for our estimation of the capitalization rate. Since the rents used in the estimating equations are monthly rents, the annual capitalization rate C_t in percentage terms is equal to (12 x 100 x exp(-α)). The estimated capitalization rates for all the AHS sample years between 1985 and 1999 are shown in figure 1. They range from 8.1 percent to 9.0 percent, and the average is 8.6 percent.[17] This average capitalization rate represents a rental equivalent of $1433 per month for an owner occupied house valued at $200,000.[18] These are gross capitalization rates, so they include any property taxes or maintenance costs that are passed on to renters.

Based on the capitalization rates and trait prices estimated using the bi-annual AHS data, we calculated Fisher price indexes and inflation rates for both rented and owner occupied housing services. Table 1 compares these inflation rates with the reported CPI inflation for rent and for owners' equivalent rent for the entire 1985-1999 period. Several differences are immediately apparent. According to the CPI, owners' equivalent rent increased more than 11 percent faster than rents over this 14-year period. According to the Fisher indexes based on our hedonic estimates, the cost of owner occupied housing services increased less than 2 percent faster than rents. Our hedonic estimates suggest that the CPI slightly underestimated inflation for rental units (-0.8 percent) and significantly overestimated inflation in the cost of owner occupied housing (9.1 percent).[19] The Boskin Commission estimated that the upward bias for shelter costs for both rental and owner occupied housing from 1976 to 1996 averaged 0.25 percent per year.

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[17] These capitalization rates are very similar to those estimated for apartment units by Sivitanides and Sivitanidou (1997). Linneman and Voith (1991) show that capitalization rates may differ systematically across homeowners as a result of tax and life cycle considerations. We abstract from these issues.

[18] $\$1433 = (.086 \times \$200{,}000)/12$

[19] If we allow the coefficient on age to vary between owners and renters, the difference between the CPI and the hedonic estimate for rents over this 14-year period would be -3.3 percent and the difference between the CPI and the hedonic estimate for owner occupied housing services would be 21.1 percent. The estimated capitalization rates in that model range from 9.4 percent to 9.8 percent with an average of 9.6 percent.

Our estimates suggest that there was a much larger upward bias for owner occupied housing costs from 1985 to 1999 but little, if any, bias for rental housing.

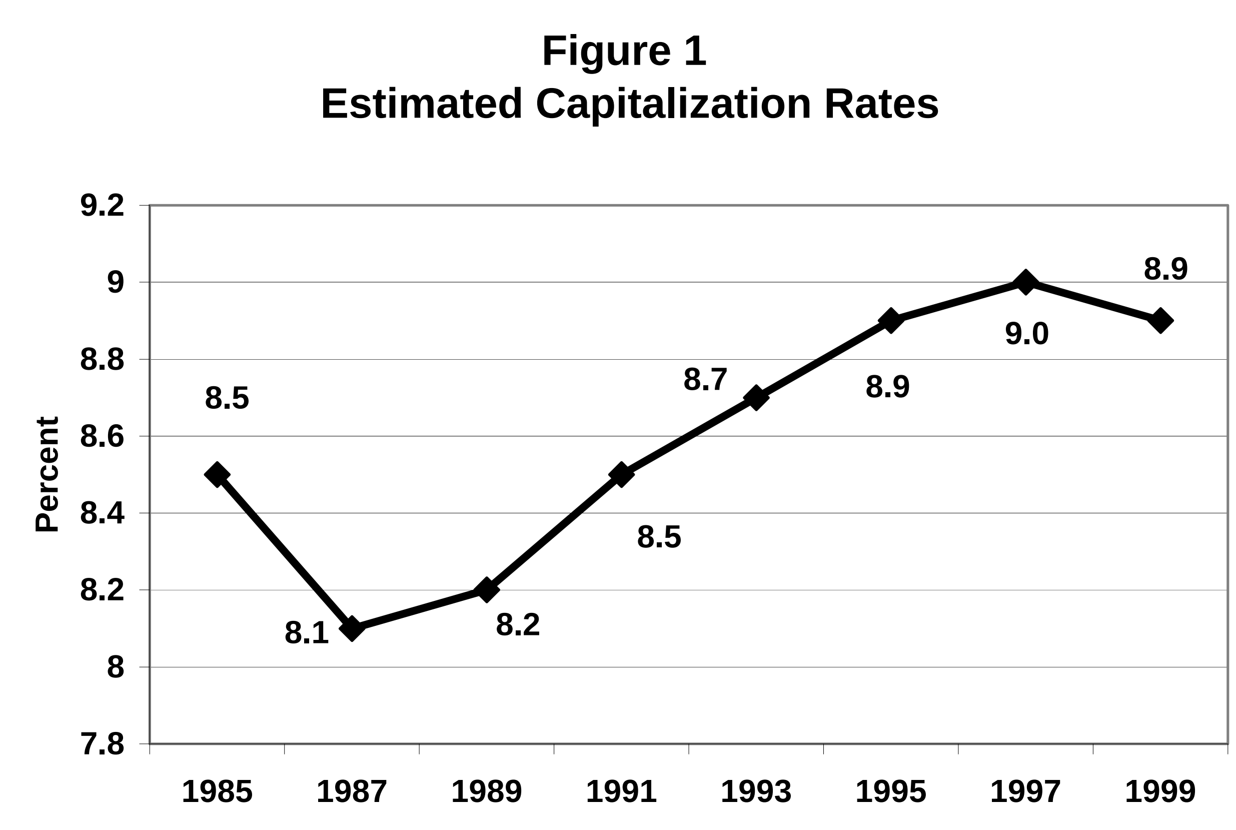


Table 1. Inflation in Housing Services: 1985-1999

Housing segment	CPI	Hedonic estimates	Difference (CPI minus hedonic)
Rental Units	56.8%	57.7%	-0.8%
Owner occupied units (Owners' equivalent rent)	68.4%	59.3%	9.1%

Table 2a shows the annualized inflation rates for rental units over successive two-year periods from 1985 to 1999 based on the CPI and our hedonic estimates, and table 2b shows the annualized cumulative rates since 1985. The period-by-period changes in the CPI for rents are much smoother than the changes in the Fisher indexes based on the hedonic model. Moreover, the differences between the two measures fluctuate in sign (table 2a, column 3 and figure 2a), suggesting that any imprecision in the hedonic based estimates is corrected over time.

Since 1993 the annualized cumulative difference between the CPI and the hedonic based measure has ranged between 0.1 percent and -0.2 percent (table 2b and figure 2b). In a separate paper (Crone, Nakamura, and Voith, 2008), we estimate that methodological issues accounted for an underestimate of rental increase of about 0.1 percent a year between 1985 and 1999.

Table 2a. Rental Inflation (Annualized Rates)

Years	CPI	Hedonic estimates	Difference (CPI minus hedonic)
85-87	4.5	5.3	-0.9
87-89	3.9	2.9	1.0
89-91	3.6	5.0	-1.4
91-93	2.3	1.7	0.7
93-95	2.5	3.2	-0.7
95-97	2.5	1.4	1.1
97-99	1.5	3.8	-2.3

Table 2b. Cumulative Rental Inflation (Annualized Rates)

Years	CPI	Hedonic estimates	Difference (CPI minus hedonic)
85-87	4.5	5.3	-0.9
85-89	4.2	4.1	0.1
85-91	4.0	4.4	-0.4
85-93	3.6	3.7	-0.1
85-95	3.4	3.6	-0.2
85-97	3.3	3.2	0.1
85-99	3.3	3.3	-0.0

Figure 2a
Difference from CPI Rent Inflation
(CPI minus hedonic)
(Annualized Rates)

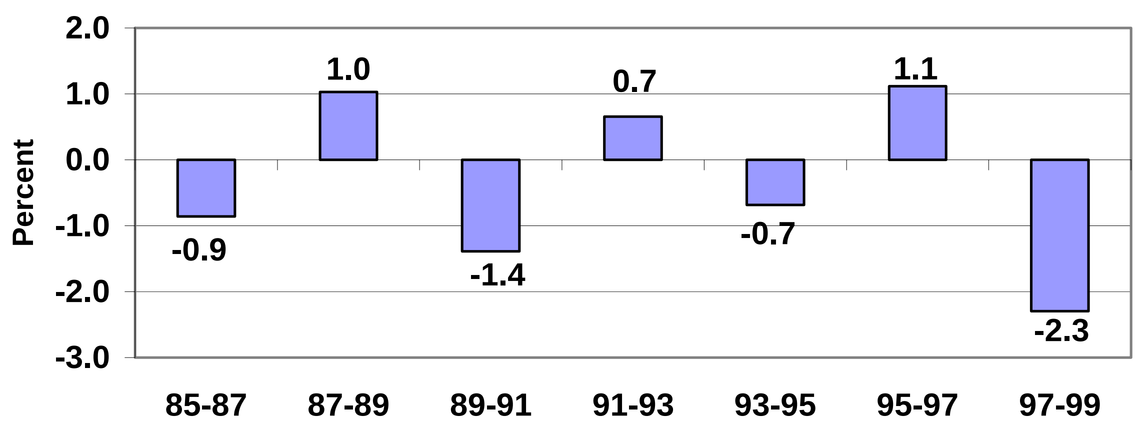


Figure 2b
Cumulative Difference from CPI Rent Inflation
(CPI minus hedonic)
(Annualized Rates)

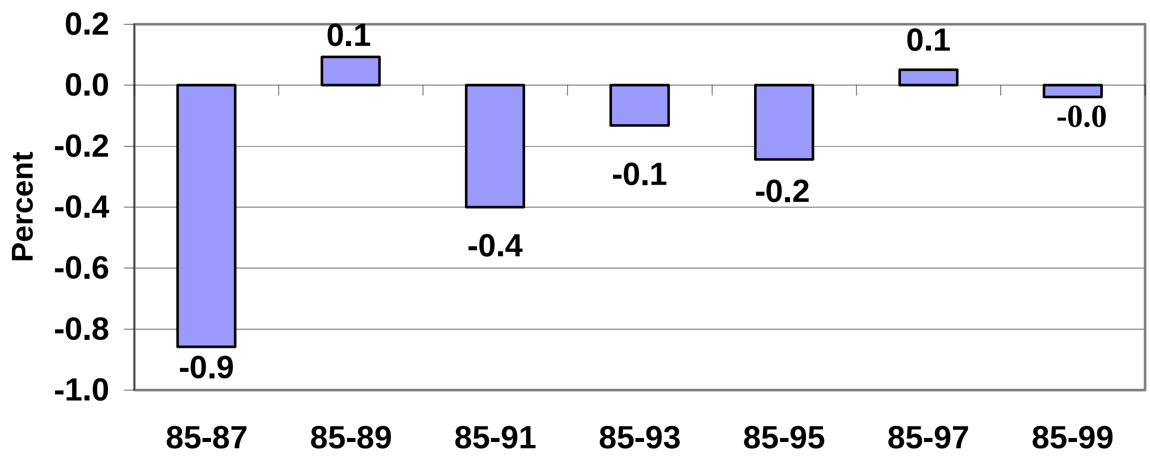


Table 3a shows the annualized inflation rates for the cost of owner occupied housing over successive two-year periods from 1985 to 1999. These estimates are based on the CPI owners' equivalent rent and our hedonic estimates, and table 3b shows the annualized cumulative rates since 1985. The hedonic estimate is higher than the CPI inflation measure in four of the two-year periods for which we estimate our index. On the other hand, it is lower than the CPI in three of the periods (table 3a and figure 3a). On an annualized basis, the cumulative difference between the CPI and our hedonic measure has been between 0.4 percent and 0.9 percent since 1991. If the hedonic estimates are a good measure of inflation in owner occupied housing over the longer term, this suggests that the CPI has overestimated owner occupied housing inflation (table 3b and figure 3b). This overestimation is explained primarily by the use, prior to 1995, of the Sauerbeck formula for matching rental and homeowner units that resulted in an overestimation of inflation for OOH costs (Armknecht et al., 1995).

6. Conclusion

In this paper we have used hedonic techniques to overcome some of the problems of measuring changes in the cost of constant quality housing services. Using American Housing Survey (AHS) data, we estimated hedonic parameters for the characteristics of rental and owner occupied units separately at two-year intervals over the period 1985 to 1999. We then combined the rental and owner occupied units to estimate the capitalization rate for homeowner units and the costs of housing services for both renters and homeowners. Using these estimates, we calculated Fisher indexes for the increase in rents and the costs of owner occupied housing services for constant quality units.

Hedonic methods are helpful in estimating rental increases, but they are even more useful for estimating changes in the cost of housing services for homeowners. Even though the U.S. Bureau of Labor Statistics (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 estimate the market value (but not the rental equivalent) of a constant quality owner occupied house in two different periods. With an estimated capitalization rate, the change in the value of the house can be translated directly into the change in the user cost of capital for the homeowner.

We estimated that the capitalization rate ranged from 8.1 percent to 9.0 percent over the period of 1985 through 1999. Our hedonic estimates imply a 59.3 percent increase in the cost of housing services for homeowners over this period, which is considerably less than the 68.4 percent increase estimated by the BLS. We estimate a 57.7 percent increase in rents over this period, which is just slightly higher than the 56.8 percent increase estimated by the BLS. We offer several possible explanations for an overestimation by the BLS of inflation for owner occupied housing services and an underestimation of rental inflation. In many cases, these explanations are based on flaws in the CPI methodology already recognized by the BLS and in some cases already remedied. However, the BLS may want to consider collecting more detailed traits on the housing units in their sample to check the inflation rates calculated using the CPI methodology against a hedonic measure.

Table 3a. Inflation for OOH Services (Annualized Rates)

Years	CPI	Hedonic estimates	Difference (CPI minus hedonic)
85-87	4.9	1.5	3.4
87-89	5.0	3.0	1.9
89-91	4.3	7.1	-2.7
91-93	3.1	2.7	0.4
93-95	3.5	4.3	-0.9
95-97	2.9	1.9	1.0
97-99	2.9	3.2	-0.4

Table 3b. Cumulative Inflation for OOH Services (Annualized Rates)

Years	CPI	Hedonic estimates	Difference (CPI minus hedonic)
85-87	4.9	1.5	3.4
85-89	4.9	2.3	2.7
85-91	4.7	3.8	0.9
85-93	4.3	3.6	0.8
85-95	4.2	3.7	0.4
85-97	4.0	3.4	0.5
85-99	3.8	3.4	0.4

Figure 3a
Difference from CPI Inflation Owner-Occupied Housing Services
(CPI minus hedonic)
(Annualized Rates)

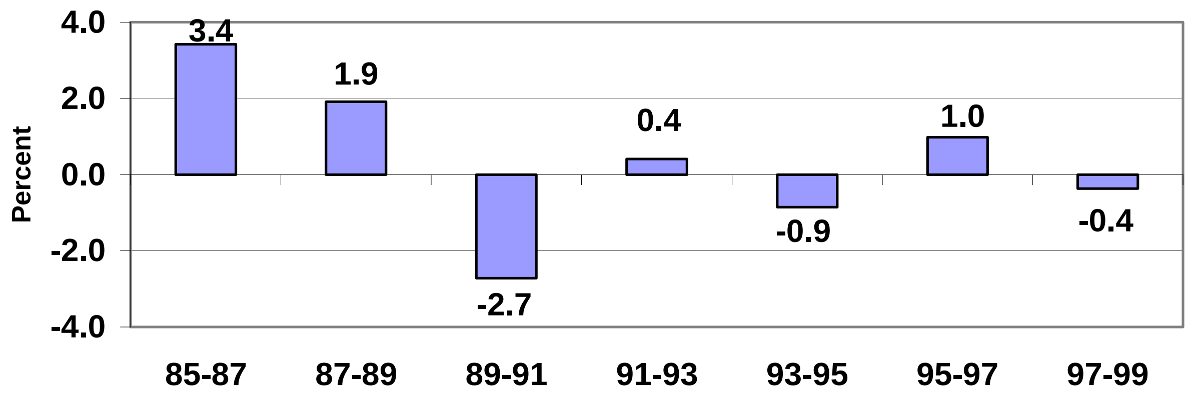
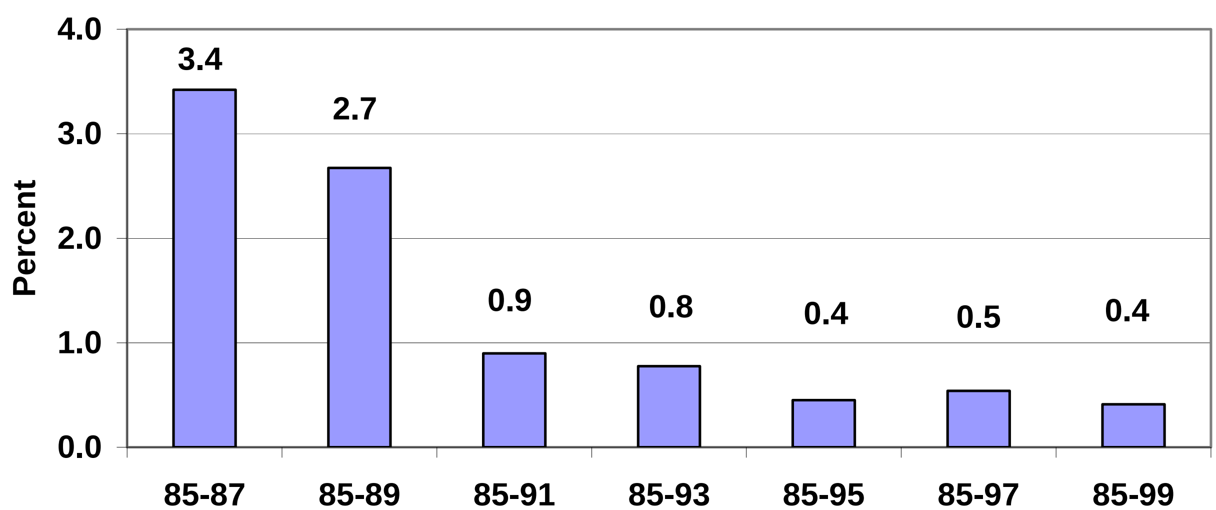


Figure 3b
Cumulative Difference from CPI Inflation
Owner-Occupied Housing Services
(CPI minus hedonic)
(Annualized Rates)



Appendix A. Estimation Results

Table A1. Samples for Calculating Fisher Index

	1985		1993		1999	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
rent	316	163	455	215	581	342
house value	72491	53187	106430	80856	141805	117513
owner dummy	0.650	0.477	0.647	0.478	0.663	0.473
number of rooms	5.5	1.8	5.6	1.9	5.6	1.8
number of bathrooms	1.4	0.6	1.5	0.6	1.6	0.6
age of structure	30	21	35	23	40	24
in a multi-unit building	0.299	0.458	0.298	0.457	0.241	0.428
garage dummy	0.555	0.497	0.572	0.495	0.605	0.489
central air dummy	0.335	0.472	0.438	0.496	0.525	0.499
holes in floor dummy	0.015	0.120	0.012	0.107	0.011	0.105
mice or rats dummy	0.046	0.210	0.027	0.161	0.177	0.382
satisfied with neighborhood (1 to 10)	8.1	2.2	8.0	2.2	7.8	2.2
MSA dummy	0.779	0.415	0.780	0.414	0.871	0.336
midwest dummy	0.248	0.432	0.241	0.428	0.267	0.442
south dummy	0.331	0.471	0.334	0.472	0.313	0.464
west dummy	0.191	0.393	0.196	0.397	0.222	0.416
Number of observations	32320		33986		45234	

Notes: MSA stands for metropolitan statistical area.

Table A2. Regression Samples

	1985		1993		1999	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
rent	323	142	450	188	545	219
house value	67660	45000	97492	67235	118326	70962
owner dummy	0.694	0.461	0.689	0.463	0.695	0.460
number of rooms	5.6	1.8	5.6	1.8	5.6	1.7
number of bathrooms	1.4	0.5	1.5	0.6	1.6	0.6
age of structure	31	21	35	23	41	24
in a multi-unit building	0.274	0.446	0.274	0.446	0.226	0.418
garage dummy	0.572	0.495	0.589	0.492	0.612	0.487
central air dummy	0.340	0.474	0.445	0.497	0.533	0.499
holes in floor dummy	0.014	0.117	0.011	0.106	0.011	0.105
mice or rats dummy	0.044	0.205	0.025	0.155	0.175	0.380
satisfied with neighborhood (1 to 10)	8.1	2.2	8.0	2.1	7.7	2.2
MSA dummy	0.776	0.417	0.776	0.417	0.866	0.340
midwest dummy	0.254	0.435	0.248	0.432	0.276	0.447
south dummy	0.336	0.472	0.340	0.474	0.323	0.468
west dummy	0.186	0.389	0.189	0.392	0.209	0.406
Number of observations	29434		30702		40434	

Notes: MSA stands for metropolitan statistical area.

Table A3. Regression Results for Rental Units

Dependent variable: Ln(Rent)	1985	1993	1999
number of rooms	0.041[a]	0.036[a]	0.052[a]
number of bathrooms	0.233[a]	0.250[a]	0.204[a]
age of structure	-0.005[a]	-0.003[a]	-0.002[a]
in a multi-unit building	0.209[a]	0.196[a]	0.122[a]
garage dummy	0.129[a]	0.092[a]	0.080[a]
central air dummy	0.157[a]	0.110[a]	0.105[a]
holes in floor dummy	-0.091[a]	-0.070[b]	-0.065[b]
mice or rats dummy	-0.086[a]	-0.016	-0.033[a]
satisfied with neighborhood (1 to 10)	0.001	0.005[b]	0.007[a]
MSA dummy	0.309[a]	0.337[a]	0.387[a]
midwest dummy	-0.237[a]	-0.338[a]	-0.240[a]
south dummy	-0.325[a]	-0.418[a]	-0.351[a]
west dummy	-0.035[b]	-0.105[a]	-0.038[a]
Constant	5.041[a]	5.355[a]	5.455[a]
Number of observations	9001	9567	12329
Adjusted R-squared	0.302	0.304	0.242
Sum of Squared Residuals	9047	10188	12600

Notes: A superscript a or b denotes a coefficient significant with a 0.99 or 0.95 level of confidence, respectively, with a two-tailed critical region. MSA stands for metropolitan statistical area.

Table A4. Regression Results for Owner Occupied Units

Dependent variable: Ln(House Value)	1985	1993	1999
number of rooms	0.114[a]	0.121[a]	0.129[a]
number of bathrooms	0.293[a]	0.312[a]	0.261[a]
age of structure	-0.0001	0.002[a]	0.001[a]
in a multi-unit building	0.168[a]	0.284[a]	0.170[a]
garage dummy	0.429[a]	0.429[a]	0.377[a]
Central air dummy	0.141[a]	0.135[a]	0.116[a]
holes in floor dummy	-0.407[a]	-0.462[a]	-0.295[a]
mice or rats dummy	-0.182[a]	-0.130[a]	-0.094[a]
satisfied with neighborhood (1 to 10)	0.031[a]	0.039[a]	0.028[a]
MSA dummy	0.330[a]	0.350[a]	0.233[a]
midwest dummy	-0.355[a]	-0.456[a]	-0.223[a]
south dummy	-0.305[a]	-0.468[a]	-0.347[a]
west dummy	0.031	-0.044[a]	0.063[a]
Constant	9.040[a]	9.172[a]	9.565[a]
Number of observations	20433	21147	28105
Adjusted R-squared	0.378	0.391	0.332
Sum of squared residuals	1796	1770	2151

Notes: A superscript a or b denotes a coefficient significant with a 0.99 or 0.95 level of confidence, respectively, with a two-tailed critical region. MSA stands for metropolitan statistical area.

Table A5. Regression Results for Renter and Homeowner Units Combined

Dependent Variable: Ln(Rent) or Ln(House Value)	1985	1993	1999
owner dummy	4.949[a]	4.922[a]	4.909[a]
number of rooms	0.100[a]	0.105[a]	0.115[a]
number of bathrooms	0.297[a]	0.314[a]	0.259[a]
age of structure	-0.002[a]	0.0003	0.00003
in a multi-unit building	0.260[a]	0.298[a]	0.214[a]
garage dummy	0.338[a]	0.321[a]	0.274[a]
central air dummy	0.154[a]	0.139[a]	0.125[a]
holes in floor dummy	-0.212[a]	-0.255[a]	-0.154[a]
mice or rats dummy	-0.130[a]	-0.068[a]	-0.078[a]
satisfied with neighborhood (1 to 10)	0.020[a]	0.026[a]	0.021[a]
MSA dummy	0.331[a]	0.356[a]	0.274[a]
midwest dummy	-0.316[a]	-0.419[a]	-0.225[a]
south dummy	-0.318[a]	-0.463[a]	-0.356[a]
west dummy	-0.005	-0.081[a]	0.016
Constant	4.370[a]	4.567[a]	4.883[a]
Number of observations	29434	30714	40434
Adjusted R-squared	0.940	0.937	0.941
Sum of squared residuals	11220	12394	15159

Notes: A superscript a or b denotes a coefficient significant with a 0.99 or 0.95 level of confidence, respectively, with a two-tailed critical region. MSA stands for metropolitan statistical area.

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