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Abstract

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Recent papers have questioned the accuracy of the Bureau of Labor Statistics' methodology for measuring rent increases and changes in implicit rents for owner-occupied housing. We compare the BLS estimates of increases in rents and owner-occupied housing costs to regression-based estimates using data 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. We estimate that between 1985 and 1999 the Consumer Price Index (CPI-U) *may have understated* the cumulative increase in rents. But any understatement was slight. On the other hand, we estimate that the CPI *overstated* the increase in the cost of housing services for homeowners by 0.4 percent on an annualized basis from 1985 to 1999.

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Hedonic Estimates of the Cost of Housing Services: Rental and Owner-Occupied Units

I. Introduction

In recent years, the accuracy and methodological consistency of the U.S. Consumer Price Index (CPI-U) and some of the index's major components have been repeatedly questioned (for example, Gordon, 1990; Reinsdorf, 1993; Boskin et al., 1996; Griliches, 1994; Diewert and Fox, 1999; and Nakamura, 1996, 1999). In particular, some have questioned whether the methods used by the Bureau of Labor Statistics (BLS) to measure rents and the housing costs of homeowners have been accurate and consistent (Boskin et al., 1996; Armknecht et al., 1995; Moulton, 1997; Gordon and vanGoethem, 2003; Crone, Nakamura, and Voith, 2004). Housing services account for one-fourth of the CPI and one-seventh of U.S. personal consumption expenditures. For rental units, housing costs are directly observed in market rents. For owner-occupied houses, there has long been agreement in the economics profession that the correct measure of the cost of housing services is the user cost of capital. Since 1983 the BLS has used the rental equivalent method for measuring the user cost of capital for owner-occupied housing; the inflation rate for rental units similar to owner-occupied units is used as a proxy for the inflation rate for the service flow from owner-occupied housing.[1]

We propose a hedonic method for consistently measuring inflation in housing services for both rental and owner-occupied units. It represents an alternative to the rental equivalent method of estimating the implied rental rate for owner-occupied housing. The method is applied

[1] See Smith et al. (1988) for a discussion of implicit rent as a measure of the user cost of capital for the marginal homeowner.

to renter and owner-occupied housing over the period from 1985 to 1999, and our empirical results suggest that the CPI may have slightly understated rental increases over that period but overstated increases in housing costs for homeowners by 0.4 percent a year.

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, which includes 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, they 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.

Since 1978, the BLS has estimated rental increases by sampling rental units on a six-month rotation. In 1999 the Bureau was obtaining rents on about 25,000 units. Unlike most prices in the CPI, rents are measured using 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 is likely to change over time either because of imperfect maintenance or through improvements made by the landlord or tenant;[2] 2) tenants' reports of changes in rents may be inaccurate;[3] and 3) tenants move, and vacant apartments, where rents are not recorded, may have a different inflation rate than continuously occupied ones.[4] The methods used by the BLS to measure rental inflation for 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, but the new methodology has not been applied retroactively.[5]

Prior to 1983, the BLS estimated homeowner expenses through estimates of individual cost components, such as mortgage interest costs, home purchase prices, insurance costs, and so forth. These homeownership expenses represented the cost of housing for homeowners in the CPI. In 1983 the BLS adopted the concept of owners' equivalent rent for the CPI (Gillingham and Lane, 1982). For the period 1983 to 1986, owners' equivalent rent was calculated by reweighting the rent sample to better represent owner-occupied units. But typical owner-occupied housing units have many characteristics that differ from rental units; 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 began imputing owners'

[2] 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.)

[3] 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, 2004.

[4] 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] 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 starting in 1978 that is intended to be consistently measured. For a discussion of the issues associated with the BLS methodology for collecting rental data, see Crone, Nakamura, and Voith (2004).

equivalent rent to a sample of owner-occupied units and matching each to a number of rental units in the same neighborhoods and with the same structural attributes as owner-occupied units. Unfortunately, the rental units to which the owner-occupied units were matched were aggregated using the 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 about 0.5 percentage point annually, and the problem was corrected in 1995. Because of the difficulty of finding rental units in neighborhoods in which homes were predominantly owner-occupied, the BLS returned in 1998 to the method used between 1983 and 1986 of reweighting rental units to obtain owners' equivalent rent.

Despite the correction of the aggregation formula in 1995, the rental units that were matched to the owner-occupied units or that were reweighted to obtain owners' equivalent rent may not reflect typical homeowner 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, and the rent may be set arbitrarily high or low because of the special circumstances under which the unit is temporarily in the rental market. 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 often subject to long-term contracts and price regulation.

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. The issue of maintaining constant quality illustrates these concerns. The CPI is meant to reflect *pure* inflation, that is, the change in rent or owner-occupied housing costs holding the quality of the unit constant. It is a well-established fact that for rental properties, rent is negatively related to age. This economic depreciation can be interpreted in one of two ways: rental properties physically depreciate over time as a result of imperfect maintenance, or embodied technological progress makes existing rental properties 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 Bureau of Labor Statistics began applying an aging adjustment to the rental index that ranges from 0.36 percent to 0.17 percent, depending on the region of the country and location. But homeowners 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 are depreciating faster than owner-occupied housing.

In this paper we develop separate price indices 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 alternate estimates are compared with measures of housing inflation from the CPI to help identify any possible bias 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 indices for rental and owner-occupied housing. Using techniques developed in Linneman (1980), Linneman and Voith (1991), and Crone, Nakamura, and Voith (2000), we estimate a capitalization rate for owner-occupied housing that yields an estimate of the value of the service flow from owner-occupied housing.

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 rates of owner-occupied housing services. Increases in the capitalization rates 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 one- or two-year intervals, it is quite possible that capitalization rates change significantly over longer periods of time. Over the 1985-99 period, we find that the capitalization rates of owner-occupied housing ranged from 8.1 percent to 9.0 percent.

III. Hedonic Approach to Measuring Inflation in Housing Services

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 (1999) for a review and references to 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 are no prominent studies using hedonic methods to construct indices of price changes for housing services.[6]

[6] House price appreciation indices are not indices of the change in 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 indices 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 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. 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:[7]

(1) $\quad LnV_{it} = \beta_t X_{it} + e_{it}$

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:

[7] 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.

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

A corresponding hedonic regression for rent is given by:

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

where:

R_{jt} is the rent for unit j in time t and

γ_t is a vector of the estimated percent of rent associated with individual traits.

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. 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 indices 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 consist 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 $W_{ot+n} \exp(B_t X_{ot+n})/W_{ot} \exp(B_t X_{ot})$, since the capitalization terms cancel out. Similarly, 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 the quantity 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 $W_{ot} \exp(B_{t+n}X_{ot})C_{t+n}/W_{ot} \exp(B_tX_{ot})C_t$. And a Paasche price index of owner-occupied housing services is $W_{ot+n} \exp(B_{t+n}X_{o\ t+n})C_{t+n} / W_{ot+n} \exp(B_tX_{o\ t+n})C_{t.}$ We can construct a Fisher ideal index of the price of owner-occupied housing service 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 the tax advantages of owner-occupied housing, mortgage rates, depreciation, 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 $W_{rt} \exp(\gamma_t X_{rt})$ 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: $C_t\ W_{ot} \exp(\beta_t X_{ot}) + W_{rt}\exp(\gamma_t X_{rt})$. Note that changes in the price indices 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 the trait prices.[8] 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) $\ln(C_t V_{it})D_o + \ln(R_{jt})D_r = \beta_t X_{mt} + e_{mt}$

where:

X_{mt} is the matrix of characteristics of homes of owners and renters; m runs from 1 to I+J, the total number of housing units;

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

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") $\ln (V_{it} + R_{jt}) = \alpha D_o + \beta_t X_{mt} + e_{mt}$

The capitalization rate $C_t = \exp(-\alpha)$ can be estimated straightforwardly in the regression (3"). Estimating (3") separately for two time periods allows the calculation of price indices for the total flows of housing services. In the pages that follow, we present hedonic-based estimates

[8] 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 these variables to be zero for owner-occupied units. Linneman and Voith (1991) investigate the appropriateness of pooling owners and renters.

of price indices for housing services based on data from the 1985 to 1999 national cross-sections of the American Housing Survey (AHS) and compare them to the BLS measures of the change in the price of housing services in the CPI.

IV. The American Housing Survey Data

Every two years the Bureau of the Census conducts a survey of 50,000 to 60,000 renter 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 for various reasons every two years and new units being added. We restricted our empirical estimates 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, 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 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 ideal indices for rents and owner-occupied housing costs as long as they did not have missing values for the traits in our regressions. A number of observations in the AHS did have missing values for particular 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.

Since missing values do not allow us to expand our AHS sample to the entire universe of housing units in the U.S., we calculate the change in owner-occupied housing 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 ideal index of housing costs. Table 1 displays the sample means and standard deviations of the variables used to estimate the Fisher ideal price index for the years 1985, 1993, and 1999.

Truncation presents another problem in the AHS data. Rent and house value both have upper bounds that change across years. Any rent or house value that exceeds the upper bound is coded at the upper limit. 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.[9] Since our purpose was to estimate increases in market rents, we also eliminated from our regression sample any rental units where the rent was in any way subsidized.[10] Our regression samples ranged from approximately 29,000 to 40,000 observations. Table 2 displays the sample

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

[10] We also did not use for the regression estimates 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.

means and standard deviations of the variables used in the regression analysis from the 1985, 1993, and 1999 cross-sections.

V. Hedonic Estimates of Rents, the Cost of Owner-Occupied Housing Services, and Capitalization Rates

The assumption that $\beta_t = \gamma_t$ puts some constraint on the choice of traits that we can use in our regression analysis. Kurz and Hoffmann (2004) 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 will 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. 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 the tables in the appendix. 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 the same sign 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 unit in an 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 in 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. However, 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 (3"). Table 3 presents the estimates for the years 1985, 1993, and 1999. We impose the constraint that $\beta_t = \gamma_t$ for all the 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 $(12 \times 100 \times \exp(-\alpha))$. The estimated capitalization rates for all the AHS sample years between 1985 and 1999 are shown in Chart 1. They range from 8.1 percent to 9.0 percent, and the average is 8.6 percent.[11] This average capitalization rate would represent a rental equivalent of $1433 per month for an owner-occupied house valued at $200,000. 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 ideal price indices and inflation rates for both rents and owner-occupied housing services. Table 4 compares these inflation rates with the CPI inflation for rent and owners' equivalent rent for the entire 1985-99 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 indices based on our hedonic estimates, the cost of owner-occupied housing services increased less than 2 percent faster than rents. In terms of possible biases in the CPI, our hedonic estimates suggest that the CPI slightly underestimated inflation for rental units (-0.8 percent) and significantly overestimated inflation

[11] 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.

in the cost of owner-occupied housing (9.1 percent).[12] 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. Our estimates suggest that there was a much larger upward bias for owner-occupied housing costs from 1985 to 1999 and that there was little, if any, bias for rental housing.

Table 5a 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 5b 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 indices based on the hedonic model. Moreover, the differences between the two measures fluctuate in sign from one period to the next (Table 5a, column 3 and Chart 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 5b and Chart 2b). In a separate paper (Crone, Nakamura, and Voith, 2004), we estimated that methodological issues accounted for an underestimate of rental increase of 0.1 percent a year between 1985 and 1999.

Table 6a shows the annualized inflation rates for the cost of owner-occupied housing over successive two-year periods from 1985 to 1999 based on the CPI owners' equivalent rent and our hedonic estimates, and Table 6b 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

[12] 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.

which we estimate our index; it is lower than the CPI in three of the periods (Table 6a and Chart 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 6b and Chart 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 owner-occupied housing costs (Armknecht et al., 1995).

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 AHS data, we estimated hedonic parameters for the characteristics of rental and owner-occupied units separately at two-year intervals between 1985 and 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. From these estimates we calculated Fisher ideal indices 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 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 (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 between 1985 and 1999. Our hedonic estimates imply a 59.3 percent increase in the cost of housing services for homeowners over this period, considerably less than the 68.4 percent increase estimated by the BLS. We estimate a 57.7 percent increase in rents over that period, 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.

The inflation rates estimated by our hedonic method are not as smooth as those estimated by the BLS for the CPI. However, they may well serve as a measure of the long-term bias in the CPI. If this is the case, the BLS may well 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.

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Table 1

Samples for Calculating Fisher Ideal 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
in an 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	

Table 2

Regression Samples

Variable	**1985** Mean	**1985** Std. Dev.	**1993** Mean	**1993** Std. Dev.	**1999** Mean	**1999** 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
in an 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	

Table 3

Regression Results for Renter and Homeowner Units Combined

Dependent Variable **Ln(Rent) or Ln(House Value)**	**1985**	**1993**	**1999**
owner dummy	4.949***	4.922***	4.909***
	(0.011)	(0.012)	(0.009)
number of rooms	0.100***	0.105***	0.115***
	(0.003)	(0.003)	(0.003)
number of bathrooms	0.297***	0.314***	0.259***
	(0.009)	(0.009)	(0.007)
age of structure	-0.002***	0.0003	0.00003
	(0.0002)	(0.0002)	(0.00015)
in a multi-unit building	0.260***	0.298***	0.214***
	(0.012)	(0.012)	(0.010)
garage dummy	0.338***	0.321***	0.274***
	(0.009)	(0.009)	(0.007)
central air dummy	0.154***	0.139***	0.125***
	(0.009)	(0.009)	(0.008)
holes in floor dummy	-0.212***	-0.255***	-0.154***
	(0.031)	(0.035)	(0.029)
mice or rats dummy	-0.130***	-0.068***	-0.078***
	(0.018)	(0.024)	(0.008)
satisfied with neighborhood (1 to 10)	0.020***	0.026***	0.021***
	(0.002)	(0.002)	(0.001)
in an MSA dummy	0.331***	0.356***	0.274***
	(0.009)	(0.009)	(0.009)
midwest dummy	-0.316***	-0.419***	-0.225***
	(0.011)	(0.011)	(0.009)
south dummy	-0.318***	-0.463***	-0.356***
	(0.011)	(0.011)	(0.010)
west dummy	-0.005	-0.081***	0.016
	(0.012)	(0.012)	(0.010)
Constant	4.370***	4.567***	4.883***
	(0.026)	(0.026)	(0.022)
Number of observations	29434	30714	40434
Adjusted R-squared	0.940	0.937	0.941
Sum of Squared Residuals	11220	12394	15159

Standard errors in parentheses

** significant at 5%; *** significant at 1%

Table 4
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 5a
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 5b
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

Table 6a
Inflation for Owner-Occupied Housing 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 6b
Cumulative Inflation for Owner-Occupied Housing Services
(Annualized Rates)

Years	**CPI**	**Hedonic**	**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

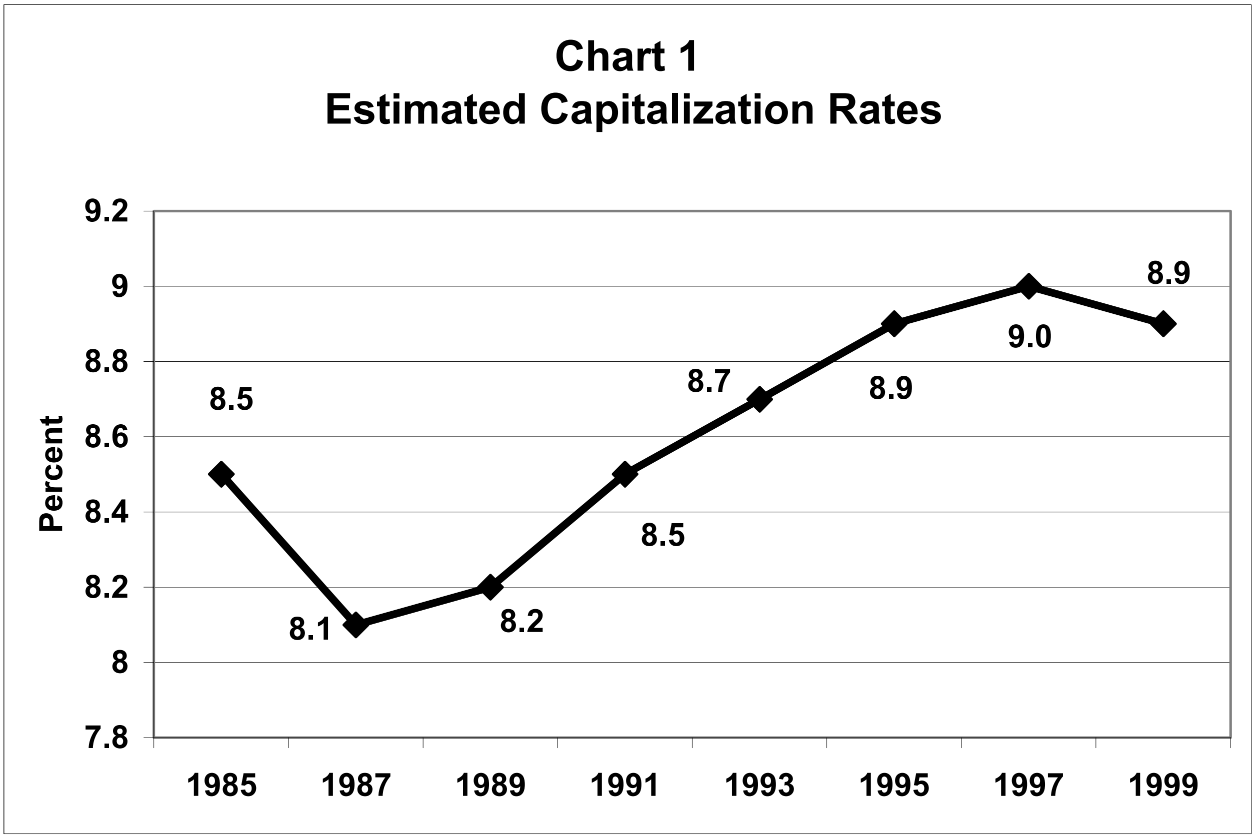
Chart 1
Estimated Capitalization Rates
Percent
9.2
9
8.8
8.6
8.4
8.2
8
7.8
1985
1987
1989
1991
1993
1995
1997
1999
8.5
8.1
8.2
8.5
8.7
8.9
9.0
8.9

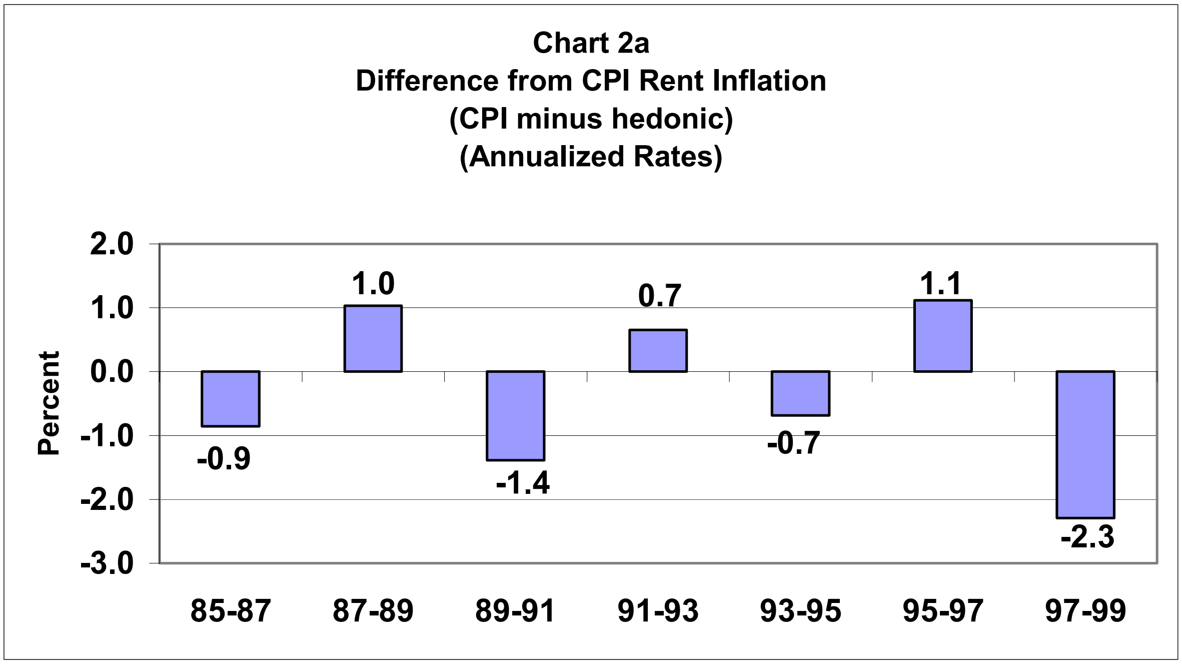

Chart 2a
Difference from CPI Rent Inflation
(CPI minus hedonic)
(Annualized Rates)
Percent
2.0
1.0
0.0
-1.0
-2.0
-3.0
-0.9
1.0
-1.4
0.7
-0.7
1.1
-2.3
85-87
87-89
89-91
91-93
93-95
95-97
97-99

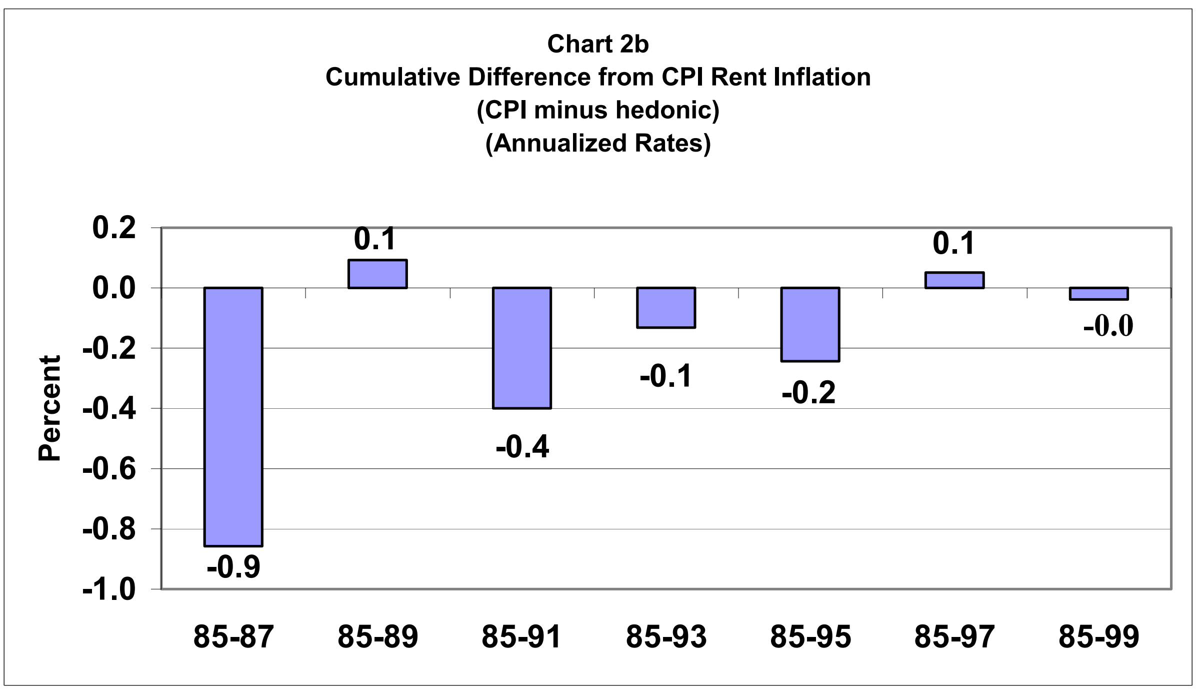

Chart 2b
Cumulative Difference from CPI Rent Inflation
(CPI minus hedonic)
(Annualized Rates)
Percent
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-0.9
0.1
-0.4
-0.1
-0.2
0.1
-0.0
85-87
85-89
85-91
85-93
85-95
85-97
85-99

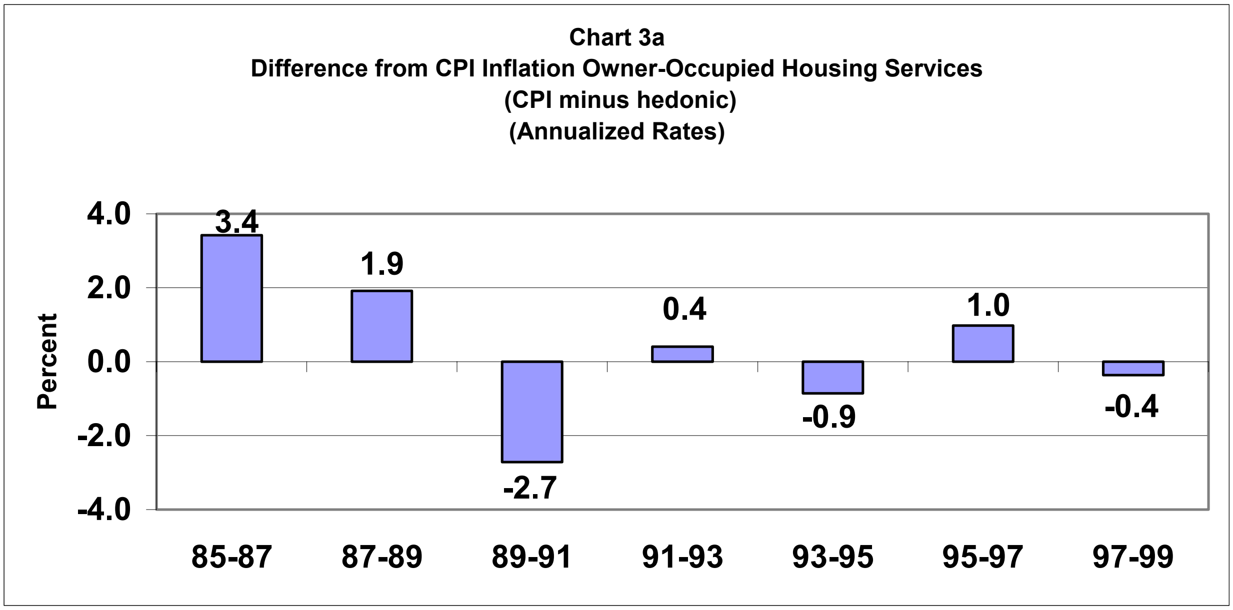
Chart 3a
Difference from CPI Inflation Owner-Occupied Housing Services
(CPI minus hedonic)
(Annualized Rates)
Percent
4.0
2.0
0.0
-2.0
-4.0
3.4
1.9
-2.7
0.4
-0.9
1.0
-0.4
85-87
87-89
89-91
91-93
93-95
95-97
97-99

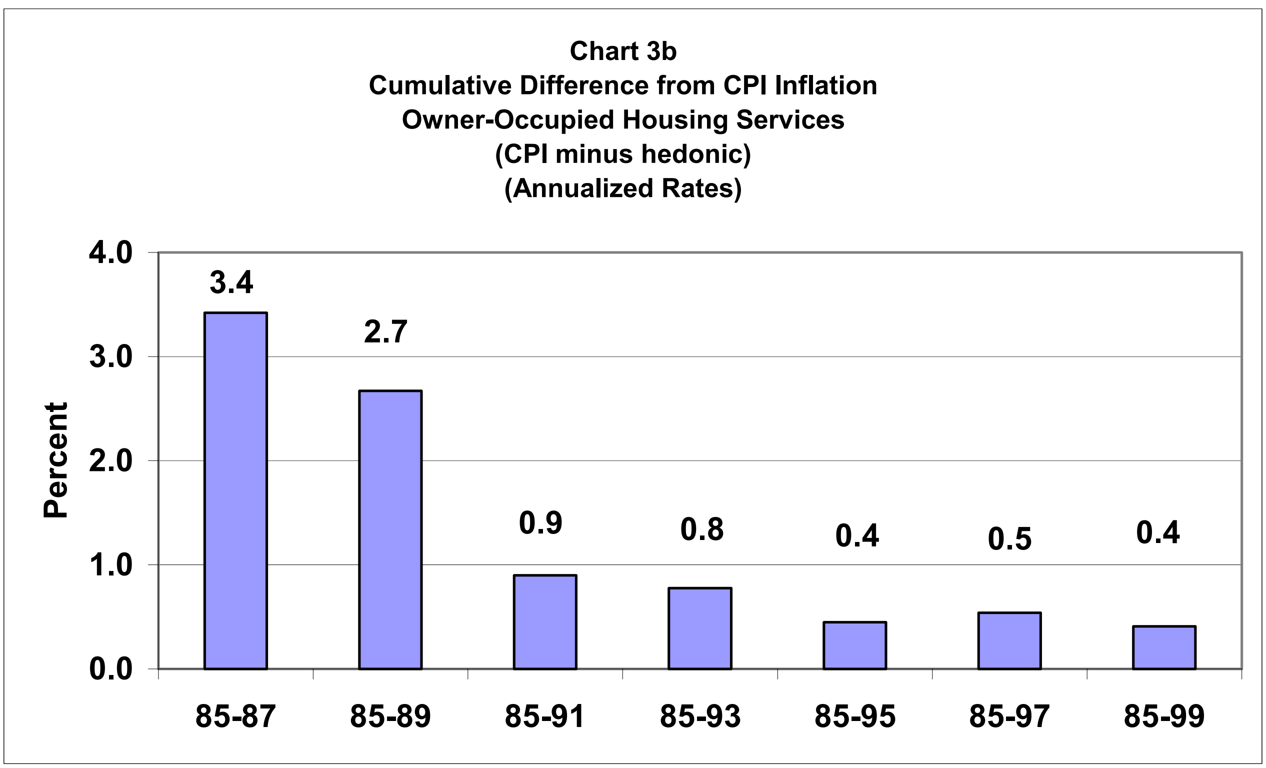
Chart 3b
Cumulative Difference from CPI Inflation
Owner-Occupied Housing Services
(CPI minus hedonic)
(Annualized Rates)
Percent
4.0
3.0
2.0
1.0
0.0
3.4
2.7
0.9
0.8
0.4
0.5
0.4
85-87
85-89
85-91
85-93
85-95
85-97
85-99

Appendix

Results for Separate Renter and Homeowner Regressions

Table A1
Regression Results for Rental Units

Dependent Variable Ln(Rent)	**1985**	**1993**	**1999**
number of rooms	0.041***	0.036***	0.052***
	(0.004)	(0.004)	(0.004)
number of bathrooms	0.233***	0.250***	0.204***
	(0.016)	(0.013)	(0.011)
age of structure	-0.005***	-0.003***	-0.002***
	(0.0003)	(0.0002)	(0.0002)
in a multi-unit building	0.209***	0.196***	0.122***
	(0.013)	(0.012)	(0.009)
garage dummy	0.129***	0.092***	0.080***
	(0.012)	(0.011)	(0.009)
central air dummy	0.157***	0.110***	0.105***
	(0.013)	(0.012)	(0.010)
holes in floor dummy	-0.091***	-0.070**	-0.065**
	(0.030)	(0.032)	(0.026)
mice or rats dummy	-0.086***	-0.016	-0.033***
	(0.020)	(0.022)	(0.011)
satisfied with neighborhood (1 to 10)	0.001	0.005**	0.007***
	(0.002)	(0.002)	(0.002)
in an MSA dummy	0.309***	0.337***	0.387***
	(0.014)	(0.013)	(0.016)
midwest dummy	-0.237***	-0.338***	-0.240***
	(0.014)	(0.014)	(0.012)
south dummy	-0.325***	-0.418***	-0.351***
	(0.015)	(0.014)	(0.012)
west dummy	-0.035**	-0.105***	-0.038***
	(0.015)	(0.014)	(0.012)
Constant	5.041***	5.355***	5.455***
	(0.036)	(0.033)	(0.031)
Number of observations	9001	9567	12329
Adjusted R-squared	0.302	0.304	0.242
Sum of Squared Residuals	9047	10188	12600

Standard errors in parentheses
** significant at 5%; *** significant at 1%

Table A2

Regression Results for Owner-Occupied Units

Dependent Variable **Ln(House Value)**	**1985**	**1993**	**1999**
number of rooms	0.114***	0.121***	0.129***
	(0.003)	(0.004)	(0.003)
number of bathrooms	0.293***	0.312***	0.261***
	(0.011)	(0.011)	(0.009)
age of structure	-0.0001	0.002***	0.001***
	(0.0003)	(0.0003)	(0.0002)
in a multi-unit building	0.168***	0.284***	0.170***
	(0.020)	(0.020)	(0.019)
garage dummy	0.429***	0.429***	0.377***
	(0.011)	(0.012)	(0.010)
Central air dummy	0.141***	0.135***	0.116***
	(0.012)	(0.012)	(0.010)
holes in floor dummy	-0.407***	-0.462***	-0.295***
	(0.053)	(0.055)	(0.049)
mice or rats dummy	-0.182***	-0.130***	-0.094***
	(0.027)	(0.038)	(0.011)
satisfied with neighborhood (1 to 10)	0.031***	0.039***	0.028***
	(0.002)	(0.002)	(0.002)
in an MSA dummy	0.330***	0.350***	0.233***
	(0.011)	(0.011)	(0.011)
midwest dummy	-0.355***	-0.456***	-0.223***
	(0.014)	(0.015)	(0.012)
south dummy	-0.305***	-0.468***	-0.347***
	(0.014)	(0.015)	(0.013)
west dummy	0.031	-0.044***	0.063***
	(0.016)	(0.016)	(0.014)
Constant	9.040***	9.172***	9.565***
	(0.032)	(0.033)	(0.028)
Number of observations	20433	21147	28105
Adjusted R-squared	0.378	0.391	0.332
Sum of Squared Residuals	1796	1770	2151

Standard errors in parentheses

** significant at 5%; *** significant at 1%