A Century of Housing Shelter Prices: How Big is the CPI Bias?*

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Introduction

This paper develops new price indexes from a variety of sources to assess the hypothesis that the Consumer Price Index (CPI) for rental shelter housing has been biased downward for its entire history since 1914. Rental shelter housing is the most important single category of the CPI, especially for those years when rent data have been used to impute price changes for owner-occupied housing. If valid, the implications of the hypothesis of downward bias would carry over to the deflator for Personal Consumption Expenditures (PCE) and, in the opposite direction, to historical measures of real PCE and real GDP.[1]

The high-water mark of widespread belief in the pervasiveness of upward bias in the Consumer Price Index (CPI) may have been reached on December 4, 1996, the day on which the Boskin Commission Report was released on Capital Hill in front of rows of television cameras and reporters.[2] Since then the Boskin conclusion has been tempered in at least three directions. First, the report itself was criticized for overstating the extent of upward quality-change bias for several products including the subject of this paper, rental shelter prices (Moulton-Moses, 1997). Second, the report appeared in a period of rapid improvement in the CPI, particularly in its treatment of substitution

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[1] Before 1983 the CPI employed its own idiosyncratic method for owner-occupied housing, while the PCE and GDP deflators used the CPI rental shelter index as the deflator for imputed rent on owner-occupied housing.

[2] The Boskin conclusion was that, as of 1995-96, the CPI was biased upward at a rate of 1.1 percent per year. Implicit in the report is the conclusion that prior to 1993 back to some unspecified date the bias rate was 1.4 percent per year. The Boskin Commission Report is listed in the references as Boskin *et. al.* (1996).

bias, so that the current CPI is substantially less vulnerable to some of the Boskin Report's criticisms. Third, there is increasing recognition that the Boskin results, which explicitly referred to the situation as of 1995-96, may not be applicable to previous historical periods.

The Logical Case for Downward Bias

For historical analysis a basic point on the direction and magnitude of bias was made by Chuck Hulten (1997) in his discussion of William Nordhaus' (1997) seminal paper on the history of the price of light. Hulten's point is general and transcends the Boskin report or any particular source of estimates of upward CPI bias, because it implies that CPI (linked to pre-1914 indexes developed by economic historians) could not logically have been upward biased by a significant amount over as long as two centuries. If the CPI had been biased upward by, say, 1.4 percent per year since 1800, as Nordhaus had speculated, then the implied standard of living of U. S. households in the year 1800, Hulten argued, would have been implausibly low. Picking up Hulten's theme, and using the hypothetical upward bias rate of 1.4 percent per year, Gordon (2001) calculated that the median household in 1800 would have been able to buy only 1.3 pounds of potatoes per day, with nothing left over for clothing, shelter, or anything else. Extending the point back to the happy, well-fed and clothed Dutch burghers depicted in the paintings of Pieter Bruegel the elder (1525-1569), the Nordhaus 1.4

percent bias would imply the purchase of only 0.8 ounces of potatoes per day, with nothing left over for anything else.

Thus there is a logical case that, if there has been an upward bias in the CPI in recent decades, it must flatten out or even become negative before some point back into the depths of history. If we make the plausible assumption that the CPI for durable goods are upward biased for the entire twentieth century, as Gordon (1990) showed for the period 1947-83, then some other major component of the CPI must have been downward biased. This paper assesses the extent of such a bias for rental shelter housing, and a companion paper (Gordon, 2001) examines new evidence showing a downward bias for apparel.[3] This set of research results finding upward bias for some products and downward bias for others echoes Jack Triplett's perceptive suggestion more than three decades ago (1971) that the overall CPI bias could go either way because the bias has different signs for different products.

Circumstantial Evidence of Downward Bias

We can compare the change in the CPI for shelter rent between the mid 1920s and the late 1990s with scattered pieces of evidence on rents and house prices. The large discrepancies revealed here could occur because of unmeasured quality change.

[3] This line of research awaits a study of the history of food prices, which is needed to complete the trilogy of necessities, food, clothing, and shelter, which together accounted for 79 percent of household expenditure for wage earners in 1918 (Brown, Table 3.9, p. 78).

Subsequent sections of the paper deal with quality change explicitly, using both formal hedonic regression analysis and a more informal assessment.

The ratio of the 1999 to 1925 value of the CPI for rental shelter is 177.5/34.6 on a base of 1982-84 = 100, that is, a ratio of 5.1.[4] The ratio for nominal gross rent per rental unit for the same years is 19.6 (see Table 1 below). The 1999-to-1925 ratio for the median price of existing single-family houses in Washington, D. C. is 22.5.[5] Amazingly close is the ratio for the same two years of nominal net residential capital stock per housing unit, 22.1.[6] These alternative indexes are all completely unadjusted for either inflation or quality change.

Brown's (1994) detailed study of household expenditure patterns allows us to narrow the comparison to a particular type of household, the "wage earner" and the "salaried worker." Here data can be used to compare 1988 with 1918, for which the CPI ratio is 5.9. The Brown data have the advantage that they refer to owners and tenants separately and to rent and utilities expenditures separately. For wage earners, the 1988-

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[4] For aggregate sources see Table 1 below.

[5] For 1925 the median asking price of existing homes in Washington DC was $7809, *Historical Statistics,* series N149. For 1999 the median price was $176,500, *Statistical Abstract* (2000), Table 1202, p. 716.

[6] For 1925 the value of net residential wealth consisted of $51.1 billion of structures (excluding land), or an average of $2,621 per each of 19.5 million dwelling units, from *Historical Statistics*, series N133. For 1998 the value was $9,405 billion, or an average of $81,783 for each of roughly 115 million units, *Statistical Abstract* (2000), Table 1222, p. 726

to-1918 ratio for rent excluding utilities is 29.1 and for rent including utilities is 25.4. For salaried workers, the ratio excluding fuel is 26.6 and including fuel is 22.9.[7]

For the 1999 to 1925 comparison, a ratio of 22 translates into an annual growth rate of 4.18 percent per year, while the CPI ratio of 5.1 translates into 2.20 percent per year, for a difference of 1.98 percent per year. This difference in growth rates overstates the amount of potential downward CPI bias by the annual growth rate in quality over the same interval. Here, the similarity of the rental and house price ratios is somewhat puzzling, since we would expect that the quality of owner-occupied houses has increased substantially more than that of rental apartments. For instance, there has not been any appreciable increase in the size of apartments; the number of rooms in units rented by wage earners was 4.9 in 1918 and by all renters was 4.3 in 1988.[8]

Why Rental Shelter Prices Represent an Appealing Research Topic

One can compile a long list of reasons to place priority on research into the historical behavior of rental shelter prices, beyond the first factor, the circumstantial evidence reviewed above implying that the CPI may incorporate a substantial downward bias over a long period of time. Second, rental shelter carries by far the largest weight in the CPI, especially when one recognizes that owner-occupied housing

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[7] For 1988 Brown (1994, Table 3.6A, p. 62) lists annual per-household expenditures on "rent" and "fuel and light" separately for each earner type. Table 7.8A, pp. 392-3, lists "tenant rent" and Table 7.9, p. 398 lists "Renter fuel" and "Renter utilities". For 1918, see Brown (1994, Table 3.6A, p. 62).

[8] Rooms per apartment for 1918 come from Brown (1994, Table 3.6A, p. 62). For 1988, we take the average of the mean values for 1987 and 1989 from the American Housing Survey data summarized in Table 2 below.

prices are proxied by the rental shelter index with a different set of weights. Third, rental units are less heterogenous in size at any given time, are more homogeneous over time, and experience quality change along fewer dimensions than owner-occupied housing units.[9] Fourth, price changes on rental units are more homogeneous across space than for owner-occupied units.[10] Fifth, discussion of tenant rent is conceptually simpler than for owner-occupied housing, where issues of the effect of tax-deductible mortgages and capital gains are central to changes in the true user cost. Rent is not tax-deductible and generates no capital gains. If changes in tax laws or capital gains affect the incentives of landlords to supply apartments, this would be reflected (perhaps after a long lag) in the cost of rental as measured by the CPI and any other alternative price index.

Because of the importance of rental shelter prices in the CPI, any finding of a significant downward bias over a long period of time would have implications for the history of inflation, economic growth and productivity change. Findings that the

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[9] In 2001 80 percent of rental units had between 3 and 5 rooms, whereas only 35 percent of owner-occupied units fell in this range. Fully 20 percent of owner-occupied units were in the top-end category of 8+ rooms, whereas only 2 percent of rental units fell into this top category. See *Statistical Abstract 2002*, Table 937, p. 599. Over time, between 1960 and 2001 the average number of rooms per owner-occupied unit rose from 5.2 to 6.2, while the average number of rooms per rental unit increased only one-third as much, from 4.0 to 4.3 rooms. These are weighted averages of size distributions given in *Statistical Abstract* 1962, Table 1353, p. 753, and *Statistical Abstract 2002*, Table 937, p. 599. The comment about dimensions of quality change is discussed further below.

[10] The startling dichotomy between selling prices of homes in coastal "glamour" cities compared to the rest of the U. S. is emphasized in Case and Shiller (2003). They contrast Boston, with a 9.1 percent annual rate of price increase during 1995-2002, with the mere 5.1 percent rate of increase in Milwaukee. For rental units, however, the differential is miniscule, admittedly over a different period of 1988-97, with annual growth rates of rents of 3.3 percent for Milwaukee and 3.0 percent for Boston, see Goodman (2003, Exhibit 1).

degree of bias differed across historical decades would imply accelerations or decelerations in economic growth that might be different than in the current official data. Evidence developed in this paper would need to be weighed against evidence of upward bias in some other categories, especially consumer durable goods, before a final verdict on the implications of historical CPI bias could be rendered.

Contributions of this Paper

There are relatively few papers that study rental shelter prices using data external to the CPI, as contrasted to those studies that have examined behavior using the CPI data sample, e.g., Randolph (1988). No paper covers our long historical period going back to 1914. Our paper is complementary to the recent pair of papers by Crone, Nakamura, and Voith (hereafter CNV, 2003a, 2003b) and shares with CNV (2003b) the development of hedonic price indexes for rental shelter based on data from the American Housing Survey (AHS) for the period 1975-2001.[11] However, we go in a different direction once the basic hedonic indexes are estimated and the CPI bias is calculated. CNV (2003b) are primarily interested in issues of functional form, whereas we are mainly interested in quality change. Since there is much more quantitative information on quality change available after 1975 than before, and even more after 1985 than before, we take advantage of the data richness of the past quarter-century to measure the rate of quality change and its determinants. This then allows us to apply

[11] The final year for CNV is 1999 and for our study is 2001.

these rates of quality change due to particular quality characteristics to earlier periods when we have evidence on some crude quality indicators (e.g., number of rooms) but not many others.

For the period 1930-75 ours is the first published study to provide quantitative estimates of rental price and quality change, building on an unpublished dissertation by Weston (1972). We bridge the data gap between the end of Weston's data in 1970 and the beginning of the AHS data in 1975 by estimating hedonic regression equations from micro Census of Housing data for the four years 1960, 1970, 1980, and 1990. Our results are complementary to the pre-1975 bias estimates of CNV (2003a), which unlike ours are not based on actual rental data but rather on a theoretical model of how particular deficiencies in CPI methodology translate into price index bias.

Three types of data allow us to push the results back before 1930. First, we use the budget studies in Brown (1994) to create indexes of rent paid per room by different classes of tenants; this allows us to link rent per room in 1918 with selected subsequent years extending up to 1988. We also develop an informal analysis of quality change from comments and data in the Brown book. Second, we compile an alternative set of data on rent per household and per room from early NBER studies of national income and wealth, especially Grebler, Blank, and Winnick (1956), allowing us to go back to 1914 and before. Third, we report on alternative rental price indexes developed by Mandelkern and Gordon (2001) for Evanston IL covering the period 1925-99, based on

newspaper listings, and in some cases tracking rent changes for apartments having the same address.

In our final analysis, we are skeptical of any mechanical attempt to adjust for quality change. By the time the AHS data (used in our and the CNV regression analyses) began in 1975, every apartment had central heating, a refrigerator, and a stove. Thus no hedonic regression analysis can estimate the value of these quality attributes. Yet we can go beyond the implicit estimates of quality change in hedonic regression analysis by conjecturing the value of converting the average American rental tenant from the typical 1918 apartment to the typical 1975 (or 2001) apartment. This analysis is analogous to the problem of quantifying the value of new durable goods. The extent of quality change over the twentieth century was not trivial and significantly reduces the magnitude of downward CPI bias.

Comparing the CPI with Gross Rents over a Near-Century

Table 1 provides our first systematic look at the data. The CPI for rental shelter is available continuously for each year from 1913, and column (1) displays the CPI for each year when we have another index to compare to the CPI. Column (2) displays the implicit rent calculated from data in Grebler, Blank, and Winnick (hereafter GBW, 1956). While based on aggregate data, this source implies an average monthly rent of $19.23 in

1914, which is not far from the $20.67 for 1918 reported in column (7) from Brown's (1994) research based on the Consumer Expenditure Survey.

The next four columns are based on official government sources. The "Weston" column (3) extracts mean rent from the Census of Housing for 1930 to 1970.[12] The next column (4) labeled "CNV Median Gross Rent" combines Census data through 1970 with AHS data beginning in 1977. The subsequent column (5) exhibits mean contract rent from the Census microdata files, and then in column (6) comes the mean contract rent from the American Housing Survey data. Any differences between the CNV, Census, and AHS columns reflect the distinction between the median used by CNV and the mean values used in our calculations from the original government sources. Column (7) extracts from Brown's (1994) budget data the monthly cost of rent for "salaried workers" over the five years that she examines.

The index numbers in the top section of Table 1 are translated into growth rates in the bottom section. Columns (8) and (9) in the bottom section show one or two differences between the growth rate of the CPI over a particular interval minus the growth rate of the alternative index displayed in that column in the top part of the table. All eight of the growth rate comparisons show that the CPI grew slower than the comparison index, except for the CNV version of the AHS index over the period 1985-95. Over 1914-30 the difference with the implicit GBW rent index was minor, a mere

[12] The Census of Housing began in 1940, but Weston was able to extract similar data from the 1930 Census of Population.

-0.43 percent per year. Over 1918-73, the difference with the Brown budget study data is much larger, -1.88 percent per year. Over 1930-70, the difference with the Weston-based data from the U. S. Census of Housing is also quite large, -2.12 percent per year, and this is identical to the difference with the CNV-calculated Census of Housing data. The next line displays the largest difference, that between the CPI and the Brown budget data for the period 1973-88, -3.10 percent per year.

The final three lines exhibit differences between the growth rates of the CPI and the AHS data, both as calculated by CNV and in our study. In our calculation (column 9) the difference in growth rates between the CPI and the AHS mean rent shrinks slowly from -1.68 percent per year in 1977-85 to -0.69 percent per year in 1995-2001, whereas in the CNV calculation (column 8) the difference starts higher and ends lower. These "differences" do not, of course, provide any evidence of bias in the CPI, since in principle the differences could be explained by quality change. Subsequently we shall estimate hedonic price indexes for the 1975-2001 period that take account of those aspects of quality change that correspond to quality characteristics reported in the AHS data.

If we were to conjecture that quality change advanced at a steady pace over the twentieth century, then the differences reported in the bottom section of Table 1 are intriguing. The differences were close to two percent per year over most of the period after 1930 and before 1989. The difference was minor during 1914-30 in the first line

and was relatively small for 1995-2001 in the last line. Obviously, a conclusion that quality change proceeded at a rate of two percent per year would explain the differences displayed in the bottom of Table 1 and reject the hypothesis that the CPI for rental shelter is downward biased over the past century. A conclusion that quality change proceeded at a rate significantly slower than two percent per year, e.g., 1.0 or 0.5 percent per year, would support the hypothesis that the CPI is downward biased.

Conceptual Issues in the Development of Rental Price Indexes

For many years owner occupancy has been the primary form of housing demand in the United States, in contrast to the early twentieth century when only about one-quarter of American households were home owners.[13] Accordingly, the vast majority of research on housing demand and housing prices has focused on owner occupiers. An advantage of this paper's research on rental price indexes is that most of the concerns of the literature on home ownership are not relevant. In fact, the central topic in theoretical models of house prices is how to translate data on home ownership costs, net of tax deductions and capital gains, into a framework of "rental equivalence."

The basic task of the CPI is to measure changes in the quality-adjusted price of a rental unit. In December, 2002, the share of the total CPI allocated to the rent index was 31.4 percent, consisting of a 6.5 percent share for rent of primary residence, 22.2 percent

[13] Brown (1994, Table 3.6A, p. 62) indicates that in 1918 only 19 percent of "laborer" households were home owners, compared to 24 percent of "wage earners" and 36 percent of "salaried" workers.

rental equivalence for owner-occupied housing, and 2.7 percent for lodging away from home (Greenlees, 2003, p. 1). The crucial point is that changes in tenant rent are imputed to owner-occupied housing by changing weights but not by creating a new and different index of the unique costs or benefits of owner occupancy. Thus the CPI makes the implicit assumption that any benefits of tax deductions or capital gains to home owners are quickly reflected in rents, as landlords in a hypothetically competitive rental market pass along their own changes in user cost to their tenants.

Of course, this implicit CPI assumption is dubious. Economists have long recognized that rental prices are "sticky," that is, slow to adjust. As documented by Genesove (1999), 29 percent of rental apartment units had no change in rent from one year to the next. Nominal rigidity was much higher among units where tenants continued from the previous year as contrasted to units where the tenants changed. Genesove also finds that units in single-unit and small buildings were much more likely to display nominal rigidity. Because apartment rents are sticky, the underlying CPI assumption that apartment rents can be translated into owner occupancy costs is problematic. Fundamental changes that influence home ownership costs, e.g., a reduction in interest rates that (as in 2001-02) allowed many homeowners permanently to reduce their true home ownership cost, may be reflected in rental costs (and hence in the CPI) only after a long lag, if at all.

It is striking how many dimensions of the literature on house prices refer back to tenant rent as a baseline for analysis. A recent example is Bajari, Benkard, and Krainer (BBK, 2003, p. 3), who translate the dependence of house price indexes on rental equivalence as follows:

> "Dougherty and Van Order [1982] were among the first to recognize that the user cost could be a good measure of inflation in the cost of housing services. They note that the user cost is a marginal rate of substitution of housing consumption for other consumption. Further, in a competitive economy, the user cost should be equal to the rental price of a single unit of housing services charged by a profit-maximizing landlord. Thus, the inherently difficult task of measuring an unobservable marginal rate of substitution is replaced by the much easier task of measuring rents."

The BBK paper makes a striking and controversial point, that all price increases on transactions in existing homes are welfare-neutral, because any benefits of capital gains to sellers are cancelled by reductions in the welfare of buyers. Welfare is increased only by construction of new homes and renovation of existing homes. Indeed, the structure of housing finance, at least in the United States, severely handicaps home renters relative to home owners, not only by providing tax deductions on mortgage interest to home owners, but also by transferring the benefits of capital gains to landlords, at least in the short run. In the long run capital gains on rental properties, as well as tax deductions available to landlords, should translate into an increased supply that drives down rents, just as (more immediately) costs of home ownership are

reduced by unrealized capital gains on houses. This process of adjustment may be inhibited by supply constraints.[14]

Díaz and Luengo-Prado (2003) provide a convincing explanation of a fundamental puzzle, which is why, in the perspective of subsidies and advantages to home ownership, all households are not owner-occupiers. They estimate the effects on the percentage of home ownership (66.5 percent in their data) of adjustment costs, uncertainty, tax deductibility, down payment percentages, and discount rates. Their analysis provides an intuitive explanation of why one-third of American households are tenants and thus the subject of this research on rental prices. Renters are young, have not yet saved the down payment necessary for home ownership, move too often to allow the advantages of home ownership to offset transaction and adjustment costs, and are subject to capital market constraints based on credit histories and "permanent" income.

The dominance of the rental equivalence concept is pervasive across papers that attempt to determine whether a particular region or country is experiencing a housing price "bubble". Ayuno and Restoy (2003) provide an example of research that bases a measure of the overpricing or underpricing of house prices on an underlying concept of rental equivalence. Using data for Spain, the UK, and the US, they interpret changes in

[14] We conjecture that supply constraints may be less significant for rental apartments, where a relatively small parcel of land can accommodate numerous apartments in a high-rise building, than for single-family houses that consume significant land for yards and streets.

house prices as overshooting or undershooting of house prices relative to the fundamental level of rents. The fundamental measure of deviations of house prices from "equilibrium" is based on the ratio of house prices to rents.

Another example of the fundamental role of rents in the analysis of house prices comes from Sinai and Souleles (2003), who demonstrate that the demand for home ownership responds positively to "rent risk," that is, the perceived variance in rental prices. If a prospective tenant anticipates that rents will be variable in the future, he or she is more likely to hedge that risk by buying a home. The Sinai-Souleles analysis seems to be limited in applicability to the U. S. housing markets with its unique institution of fixed-rate long-term mortgages. In this environment, home buyers can eliminate almost all uncertainty about the cost of mortgage finance (not, of course, energy or maintenance costs) by switching from uncertain future rents to home-ownership with a fixed-rate mortgage. Likewise, the analysis is quite dependent on a past environment when inflation in rents was relatively rapid. In a hypothetical future environment of low overall inflation, eventually translated into low rent inflation, the advantages of home ownership would diminish accordingly.

The Analytical Case for Downward Bias in the CPI for Rent

Throughout its history the CPI has measured tenant rent. Beginning in 1983 (for the CPI-U, 1985 for the CPI-W), the BLS adopted the "rental equivalence" approach to

measuring price changes for owner-occupied housing. This attempts to measure the change in the amount a homeowner would pay to rent his or her home in a competitive market. The index used for homeownership does not collect new data but rather reweights the rent sample to apply to owner-occupied units. Between 1987 and 1997 the prices of owner units were moved by rent changes for rental units that are matched to a CPI owner sample based on similar location, structure type, age, number of rooms, and type of air conditioning. Beginning in 1998 the owner sample was dropped due to the difficulty of finding renter-occupied units in neighborhoods consisting mostly or entirely of owner-occupied units and the methodology returned to the same as during the 1983-86 period, namely to reweight the rent sample to represent owner-occupied units.[15]

The *ex-ante* assumption of downward bias in the CPI is based on more than the circumstantial evidence reviewed above. The BLS itself studied and then, beginning in 1988, corrected aging bias that results from the neglect of the fact that a given rental unit systematically experience a decline in rent as the result of depreciation. The extent of aging bias was initially revealed in a BLS research paper based on the hedonic regression methodology (Randolph, 1988), and since 1988 the CPI for rental shelter has been corrected by location-specific aging factors based on the hedonic regression. The annual correction for depreciation ranges from a high of 0.36 percent in major

[15] Facts in this paragraph come from Placek and Baskin (1996).

northeastern cities to 0.17 percent in the south (Lane, Randolph, and Berenson, 1988), and so the CPI for shelter is presumed to be biased downward by this amount prior to 1988.

Less well known is the nonresponse bias, which is the major focus of CNV (2003a). Beginning in 1942 the BLS began collecting data on rent changes from tenants rather than landlords. This poses the major problem that rent increases tend to take place when one tenant departs and another arrives, but the departing tenant is not reached by the BLS survey while the arriving tenant may have no knowledge of the rent paid by the previous tenant. CNV (2003a) estimate that over the period 1942-77 roughly one-third of rent increases failed to be recorded, leading to a major downward bias that they estimate to be roughly 1.5 percent per year.

Methodological improvements in the CPI gradually eliminated nonresponse bias.[16] Beginning in 1978 the size of the BLS sample was reduced with the explicit intention of giving field agents more time to capture rent increases that occurred when a tenant moved, and also giving them the latitude to interview landlords and building managers to obtain data on rent changes. In 1985 a correction was introduced for the bias associated with vacant units, involving the imputation of rent changes for vacant units based on rent changes experienced in occupied units in the same location. Finally in 1994 the method was changed to eliminate a recall bias that had been

[16] This history of CPI improvements is taken from CNV (2003a), pp. 11-12.

introduced in 1978 when respondents were asked not only about the current month's rent but also the previous month's rent. Now the monthly rate of rental inflation is calculated as the sixth root of the average six-month inflation rate (since the previous interview taken six months earlier), and this results in roughly a three-month lag in reporting of changes in the rental inflation rate (Armknecht, Moulton, and Stewart, 1995).

We have seen in Table 1 that over the period from 1930 to 1985 or 1988, the CPI for rent increases more slowly than unadjusted mean rent at a differential rate of greater than two percent per year. CNV (2003a) present adjustments based on a theoretical model of nonresponse bias; their average bias correction for 1930-85 is 1.6 percent per year for their basic estimate and 1.4 percent per year for their "conservative" alternative estimate. We shall return to a discussion of these bias corrections when we present our own evidence for sub-periods that overlap with the CNV results.

Hedonic Regression Estimates of Rents from AHS Data

All hedonic regression studies share the standard issues that arise in estimation using cross-section data, including coping with colinearity, potential nonnormal errors, variables subject to measurement error, and choice of functional form in relationships that may be nonlinear. Most of the literature on hedonic price index methodology for housing, e.g., Wallace (1996), Meese-Wallace (1991, 1997), and Sheppard (1999), refers to

the sales price of houses, not rents paid by tenants. Nevertheless, some of the issues confronted in studies of house prices apply to tenant rents as well. Housing markets are characterized by search, imperfect information, and the competition between newly constructed homes and existing units.

Housing, both owner-occupied and tenant-occupied, is very heterogeneous, having in common with such products as automobiles extreme complexity but with the added dimensions of location across regions, rural vs. urban, and location within metropolitan areas. Houses tend to cost less in the south and more in the west, and they tend to cost more in the suburbs than in the central city, partly because the quantity of land that comes with the house is seldom revealed in the data. As noted by Sheppard (1999, p. 1616), "it is surprising how many hedonic models lack either a variable for land area, or a variable that explicitly identifies the location of the structure." The importance of location in determining house prices leads to the related problem that observations may lack stochastic independence due to spatial autocorrelation, the tendency of the error in one observation to be correlated with those observations that are located nearby. We might find, for instance, that house prices are higher in a particular suburb or enclave that has any combination of excellent schools, unusually good public services, or unusually low property taxes.[17]

[17] Two classic "enclaves" with high house prices are Piedmont, tucked inside Oakland, California, and Kenilworth, wedged between Winnetka and Wilmette, Illinois.

Our hedonic study of rents from the AHS shares with CNV (2003b) the absence of data on location, except for four regions of the country and urban vs. nonurban location. Thus we are unable to include factors determining the value of land, the quality of local schools, or nearby amenities including oceans, lakes, parks, or open space. To the extent that these left-out determinants of house prices and rent are correlated with included variables, then coefficients on those variables will be biased. Fortunately, the issue of missing information on land value and other location-related variables is less serious for this study of rents than for studies of house prices, since rental units typically have little or no attached land and are more homogeneous than owner-occupied units in many dimensions.[18]

Mean Values

The AHS data examined in our hedonic regression study extends from 1975 to 2001 and covers only odd-numbered years. Details of sources and data construction, and a discussion of problems and weaknesses in the AHS data, appear in the Data Appendix. A problem with the AHS data set that determines our method of presentation is that the data consists of two separate panel data sets covering, respectively, 1975-83 and 1985-2001. The samples are different and the number of variables included jumps in the second data set. As CNV (2003b, p. 8) also found,

[18] Randolph (1988) has additional locational data, namely a large number of separate metropolitan area locational variables. Unfortunately Randolph's estimates are of little value for this study, as he uses only a single year of data (1983) and thus cannot estimate a hedonic price index.

estimated regression coefficients for the time period 1983-85 are problematic because of the lack of homogeneity of the panels between 1983 and 1985.

Table 2 displays for 1975, 1985, 1993, and 2001, the mean values of rent, of four quantitative explanatory variables, and percentage means for a host of additional variables represented in the regression analysis as dummy variables. The top row showing mean rent corresponds to the "AHS" column in Table 1 above. Particularly interesting on the second line is the size of the rental unit measured in square feet (available only starting in 1985), and this increases remarkably little in contrast to the much more rapid growth in the size of new single-family houses, with a 1970-2001 increase in median square feet of 52 percent and in mean square feet of 55 percent.[19] Other measures of size also show little increase between 1975 and 2001. There is a large jump in average age which presumably reflects changes in the panel of units.

The quality characteristics in Table 1 are divided into four sections, those representing location, positive quality attributes, negative physical and environmental characteristics, and finally special aspects of rental finance, e.g., whether the unit is in public housing and/or carries a subsidy. While the size of rental units does not increase appreciably over time, there is a marked improvement in several other measures of quality between 1975 and 2001. The presence of air conditioning increases from 15

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[19] *Statistical Abstract*, 1987, Table 1273, p. 706, and 2002, Table 922, p. 591. The median went from 1385 square feet in 1970 to 2103 square feet in 2001. By comparison a sample of new houses started in the first half of 1950 had an average floor area of only 983 square feet (Grebler-Blank-Winnick, 1956, p. 119).

percent of the units in 1975 to 42 percent in 2001, while multiple bathrooms increases from 7 to 18 percent. Units having no sewer connection decreased from 16 percent in 1975 to 6 percent in 2001. There is little change in the variables in the bottom of the table measuring negative externalities.

Regression Estimates

Estimated coefficients for the full set of available variables are shown separately in Table 3 for three periods, the first panel covering 1975-83, and the second panel covering 1985-2001 divided at 1995.[20] Explanatory variables are listed in the same order as in Table 2. All regressions are estimated in double-log form and thus differ from the Box-Cox flexible functional form estimated by CNV (2003b) and the semi-log form used by Randolph (1988).[21] All coefficients displayed in Table 3 are significant at the 1 percent level or better, which is perhaps not surprising in light of the enormous sample sizes of between 40,000 and 55,000 observations in the three regressions. All coefficients appear to have correct signs, except for two negative environmental variables ("Noise Problem" and "Neighborhood bothersome") which have small positive coefficients. The regional and urban coefficients are quite large, and estimated hedonic price indexes that omit regional effects will miss changes in prices due to the shift of the population from the Northeast and Midwest to the South and West.

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[20] Note to discussant: In 1997 the AHS shifted to collecting its data on laptop computers. The presentation of the data changes in 1997 in the underlying computer file, and time constraints prevent us from fully exploiting the post-1995 data in this initial draft of the paper.

[21] CNV (2003b, Table 5) shows that the average rate of increase of their hedonic price index is insensitive to alternative functional forms.

The time dummy coefficients at the bottom of Table 3 provide an alternative measure of inflation for every two years over the period 1975-2001. After completing our discussion of the regression results, we will examine the implications of these estimated time dummy coefficients for annual rates of change over specified intervals. At that point we will compare our results with the CPI and the hedonic regression results of CNV (2003b).

The Effects of Quality Change: A "Stripping Exercise"

In addition to estimating hedonic price indexes using all the available AHS data, we also want to look more closely at the sources and magnitude of quality change. Our basic question is by how much we would overstate the rate of change in rents if we had fewer or no quality change variables. Asking this question another way, what is the difference between changes over time in the hedonic price index versus mean contract rent, and which explanatory variables contribute to this difference? In this exercise it is important to distinguish between true changes in quality and changes in other explanatory variables that do not represent changes in quality, i.e., locational variables and government-related variables (public housing and subsidized housing).

To implement this distinction between quality and non-quality explanatory variables, we remove variables in several steps. This is done for 1975-85 in Table 4, 1985-95 in Table 5, and 1995-2001 in Table 6. The first step is to remove all quality variables other than those available in Weston's analysis of the 1930-70 period

(discussed below). Thus the second column retains the number of rooms, age, and incompleteness of plumbing fixtures. The housing subsidy variables are added back in in the third and fourth columns, and the fourth column removes all remaining quality variables. The final column removes all explanatory variables other than the time dummies.

Comparing the first and second column provides evidence on the effect of quality variables not available to Weston, especially multiple bathrooms, air conditioning, and presence of an elevator. For 1975-85 these quality variables explain 0.9 percent per year of price change, and a comparison of the first and fourth columns indicates that removing all quality variables (while leaving in the regional and subsidy dummies) explains 1.3 percent per year of price change. Another 1.3 percent per year is explained by the regional and subsidy effects, that is, price change would have been higher if our regressions did not take account of a movement toward the western region and to urban areas where house prices are higher.[22]

Table 5 carries out the same exercise for the subsequent decade 1985-95 when our set of explanatory variables is considerably richer. However the result in going from the first to second column is the same, 0.9 percent per year of price change is explained

[22] These annual rates of change are calculated by converting the time dummy coefficients, which are in the form of decimal log changes, into percents and dividing by the 10 years covered in Table 4. Thus the cumulative 1975-85 price increase in the first column is 82 percent and in the last column is 108 percent, implying a difference of 2.6 percent per year. Of this, 1.3 percent represents the contribution of quality variables and the remaining 1.3 percent reflects the contribution of regional and subsidy variables.

by the combined effects of the long list of variables not available to Weston. Surprisingly, omitting the remaining quality variables in going from the second to fourth column actually reduces the cumulative price increase, probably reflecting the jump in the average age of rental units shown previously in Table 2. For the 1985-95 decade, a comparison of the final two columns indicates that removing the regional and subsidy variables does not make any difference even though the positive coefficients on "west" and "urban" are considerably higher in Table 5 than in Table 4.

Table 6 prevents results for 1995-2001 based on an incomplete set of variables. The annual rate of price change explained by quality change in going from the first to second column of Table 6 is 0.67 percent per year, but again going from column 2 to column 4 reveals a quality deterioration that may be explained by increasing age. Since the sharp jump in age in going from 1985 to 1993 to 2001 (see Table 2) is implausible, it may reflect an inconsistency in the AHS sample for which we have not yet found an explanation.[23] Again, as in 1985-95, removal of the regional dummy variables has no effect on price change, and there are no variables in this data set for public housing or subsidies.

[23] One source of inconsistency in the AHS sample is that the 1975-83 panel contains six age subcategories of which the oldest is "built before 1939" while the 1985-2001 panel contains nine age subcategories of which the oldest is "built before 1919." This inconsistency would cause approximate age to jump spuriously from 1975 to 1985 but not after 1985.

Hedonic Regressions Based on Census Microdata

A supplementary set of hedonic regressions is estimated from the Census of Housing microdata file, and here we have an amazing sample size of over 750,000, but a much smaller set of quality change variables lacking even any control for air conditioning. In Table 7 we present in the first column the full hedonic regression result, in column two the effect of removing the quality variables, and in column three the effect of removing the regional variables. The regional variables make no difference throughout, and removing the quality variables has an effect that varies over time. Looking only at 1960-70, the price increase in the second column is 10 percent faster than in the first column, indicating a quality effect of 1.0 percent per annum. However the quality effect declines to 0.6 percent per annum for 1960-80 and to 0.37 percent per annum for 1960-90.

The results in Table 4-7 are converted to annual growth rates and summarized in Table 9. The four lines represent the period of the Census data (1960-90) and the three sub-periods of the AHS data (1975-85, 1985-95, and 1995-2001). The first column displays the baseline regression results of CNV (2003b), also based on AHS data but ending in 1995. Their price increase in column (1) is substantially faster than ours in column (2) for 1975-85 but is very close in 1985-95. As discussed above, removing the quality variables other than rooms, age, and plumbing completeness yields measures of the annual rate of quality change in the three AHS periods of 0.83, 0.88, and 0.74

percent, respectively, an amazingly consistent record. For the Census data (comparing columns and 5) the average quality change effect is a much smaller 0.37 percent per year, presumably because the age variable is operating in a negative direction after 1970.

Additional Evidence Not Based on Regression Analysis

The Weston Data and Analysis

Our main source of changes in rent for the period 1930-70 comes from an unpublished dissertation by Rafael Weston (1972). His data originate in frequency table form published in the 1940, 1950, and 1960 Census of Housing volumes and preliminary data for 1970. While 1940 was the first year in which the Census of Housing was conducted, he was able to obtain corresponding data from the 1930 Census of Population.

Weston's quality characteristics are based on whether a unit was inside or outside a SMSA, its Census geographic region, the age of the unit, the number of rooms, completeness of plumbing, and 'condition,' which in turn is either "dilapidated" or "not dilapidated" as subjectively assigned by the Census interviewer. The published frequency tables contain these characteristics cross classified by rent and region but not by one another. An important advantage of the data is that the number of rental units in each quality category is provided, and this allows us to calculate rental expenditure in each category and thus to develop a price index based on expenditure weights. To

generate a full cross-classification from this limited data set, Weston supposed a multinomial model for each variable and fit the data to log-normal distribution using a complex ANOVA based methodology. He then conducted an analysis of quality change, measuring the implied quality change associated with each variable and its interaction terms. Weston produced price indexes for both house prices and rents.

Table 9 in the first column copies from Table 1 the mean gross rent data that Weston obtained from the Census. As calculated in Table 1, this series increases 2.1 percent per year more rapidly than the CPI for rent over the period 1930-70. Displayed in the second column is a quality-corrected price index that Weston calculated from his own data. Because Weston's explanation of his methodology is quite obscure, we have calculated an alternative quality-adjusted "Tornqvist" price index that calculates the rent change separately for each of Weston's cells (e.g., two rooms, complete plumbing, not dilapidated) and then aggregates the separate log rent changes by the average nominal rental expenditure in each cell in the first and second year of the comparison. Thus log rent changes in each cell from 1930 to 1940 are aggregated using the nominal expenditure share of that cell averaged between the 1930 and 1940 value.

The two right-hand columns compute an implicit quality index as the ratio of an index of mean gross rent to each of the two price increases. If rent increases faster than a price index, this implies that quality has increased. Quite surprisingly, there was no improvement in quality between 1930 and 1960. A deterioration in quality during the

1930s was just offset by a small improvement in quality in 1950-60. Only in the final decade 1960-70 did quality improve rapidly.

The bottom part of Table 9 calculates annual growth rates for each decade and for the four decades taken together. Over the full period 1930-70, the Weston price index increases at 0.44 percent per year less than mean gross rent, and the Tornqvist price index increases at 0.33 percent per year less, implying implicit quality change indexes of the same magnitude.

This leaves us with the puzzle as to why quality change was so slow in the period 1930-60 and then accelerated so much from 1960 to 1970. Several answers are suggested in Table 10, which provides means of the main Weston quality variables. First, due to lack of construction during the Great Depression, average age increased sharply from 1930 to 1940, with a drop in the number of units of 10 years or younger from 30 to 11 percent. Going in the same direction, and probably more important, was a decline in the average number of rooms from 4.65 in 1930 to 3.81 in 1950, followed by a slight recovery to 3.91 in 1960 and then a big jump to 4.89 in 1970. The other two quality variables improved steadily, with a decline in "dilapidated" from 17 percent in 1930 to 3 percent in 1970, and in partial or no plumbing from 43 percent in 1930 to 7 percent in 1970. Shown below the plumbing percentages is the implicit value of plumbing, measured as the ratio of the rent of a unit with complete plumbing to a unit lacking plumbing, calculated cell-by-cell and weighted by the number of units in each

cell.[24] Below we attempt to make a rough correction for the value of improvements over time in heating, plumbing, and electrification.

Because Weston's quality correction for 1960-70 is so much larger than for the other decades, it is worth checking Weston's results against the Census microdata that was used to develop the hedonic regressions of Table 7. As shown in Table 9, the unadjusted annual growth rate of rent for 1960-70 is 4.35 percent for Weston and in Table 11 is 4.62 percent for the Census microdata. The Weston price index based on the Tornqvist method increases at 2.73 percent per year compared to 3.6 percent for the Census hedonic price index of Table 7. The implicit increase in quality occurs at a rate of 1.5 percent for Weston and 1.0 percent for the Census. An interesting similarity is the implicit value of plumbing. The bottom line of Table 10 shows that the average value of plumbing is to make rent 1.77 times higher than without plumbing, or to make the log 0.57 higher. This is remarkably close to the coefficient for absence of plumbing of -0.62 in the Census microdata regression in Table 7.

The major discrepancy between Weston and the Census microdata concerns the change in the number of rooms from 1960 to 1970. There was virtually no change in the Census, only from 3.93 total rooms to 3.99 total rooms, in contrast to Weston's jump in Table 10 from 3.91 to 4.89. It is possible that the Weston data on mean rooms reflect a coding error, or the fact that he was using a preliminary summary of 1970 Census data.

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[24] Each "cell" shows the rent and the number of units in every combination of quality attribute, e.g., a two-room apartment more than ten years old, not dilapidated, and with full plumbing.

We note that total rooms in the AHS data were much closer to the 1970 Census figure throughout 1975-2001, ranging from 4.08 in 1975 to 4.40 in 2001. Accordingly, we discount the Weston conclusion on quality change in the 1960-70 decade and prefer the conclusion of the hedonic price index developed from the Census microdata.

Brown's Evidence on Quality Change

In Table 1 we have already examined Brown's rental prices from five budget studies based on CES data spanning the period 1918-88. We found that over the 1918-73 period, Brown's rental price per unit increased at about 1.9 percent per year faster than the CPI, quite similar to the difference of about 2.1 percent per year exhibited by the Weston data and the CNV calculation of median gross rent from the Census of Housing. Going beyond raw rent data, Brown's book contains a wealth of information on quality change.

An initial problem is that all of Brown's data from the CES on household expenditures by type (types of food, types of clothing, shelter, fuel, home furnishings etc.) are listed separately for different classes of workers – laborers, wage earners, and salaried workers. Managerial employees and owners of small businesses are excluded from the CES source. As a first attempt to extract some useful information about changes in shelter quality, we average together the percentages displayed for wage earners and salaried workers. This omits laborers at the low end and managerial and self-employed business people at the high end. Also, the data generally refer to urban

and nonfarm rural families and omit living conditions on farms, where to be sure the role of rental tenancy was quite different than in nonfarm households. Brown's study explicitly discusses the "abysmal" living conditions experienced by black households but does not provide enough information to provide weighted averages for the rental tenant population as a whole.

Of the quality changes that Brown quantifies and/or discusses over the five years of her study (as shown above in Table 1), we are primarily interested in electrification, heating, plumbing, and household appliances. Of these only the presence or absence of "complete" plumbing facilities is taken into account in the Weston study summarized in Tables 9 and 10. The best that we can do to extract data from the Brown study is presented in Table 12. As shown there, the definitions of variables tend to differ from one year to the next, and there is progressively less detail shown on the quality of rental apartments in each year after the initial year of 1918.

Two surprising facts are listed at the top of Table 12. Rooms per rental unit were 5.3 in 1918 and 5.2 in 1935, as compared to Weston's figure for 1930 of 4.7 rooms. The second surprise, doubtless related to the first, is that more than half of the rental units in both 1918 and 1935 were houses rather than apartments. Thus the 1918 households surveyed by the CES cannot be accurately characterized as living in dark, dank tenements, since more than half of them lived in houses. Presumably these were small houses typical of Chicago's "bungalow belt" and similar areas of other cities, but at least

these rental tenants did have small yards and outside windows on all four sides.[25] Even in the lowest "laborer" class houses accounted for 56 percent of rental units. In contrast in 2001 "single-family detached and attached units and mobile homes" accounted for only 36 percent of rental units.[26]

As of 1918 electrification of the urban and nonfarm rural population had reached the halfway mark, and the task of spreading electrification to the nonrural population was largely complete by 1935 and totally complete by 1950. Electrification came sooner to large cities than smaller towns, and since rental units were predominately located in large cities, it is likely that the data on the third line of Table 11 understate the spread of electrification to tenant-occupied units in 1918 and 1935.

In contrast central heating was still rare in 1918 and even in 1935. Roughly half the rooms in tenant-occupied units in 1918 were "equipped for heating," but this usually meant some kind of stove that heated a single room, often fueled by coal. Central heating did not reach a penetration of 50 percent until sometime between 1935 and 1973.

Indoor plumbing came to the rental unit earlier than central heating. By 1918 almost 80 percent of units had an indoor toilet and almost two-thirds had a bathroom. By 1935 80 percent had not just electricity but also both hot running water and a flush

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[25] Brown (1994, p. 40) indicates that median household income in the CES sample was $1400 in 1918. The mean income for her three classes are $1037 for laborers, $1344 for wage earners, and $2272 for salaried workers.
[26] *Statistical Abstract 2002*, Table 937, p. 599.

toilet. Thus, while there was a substantial further spread of indoor plumbing after 1918, much of the transition had already taken place in prior years. The data exhibit a contradiction for 1950, since it cannot be true simultaneously that 84 percent of all units were equipped with a bathroom, hot running water, and a flush toilet, while at the same time 34 percent "lacked full plumbing." The mean percentage lacking full plumbing in the Weston data in Table 10 for 1950 was 32 percent; the Weston number of 18 percent for 1960 agrees roughly with the Census number of 16 percent in Table 11.

Some additional insight into the quality of housing units (both tenant-occupied and owner-occupied) in 1935 can be obtained the description of a "typical American home" from U. S. BLS (1935) as quoted by Brown (1994, p. 126):

> "single-family dwelling, about 19 years old, of wood or frame construction containing five rooms. It is equipped with either bathtub or shower, indoor water-closet, uses electricity for lighting and gas for cooking. For the country as a whole, reliance is placed predominantly on heating stoves for heat, although over 31% of all dwelling units use warm-air furnaces. Coal is the principal fuel used."

Not much change was registered in 1950, except for the conversion to central heating, and the addition of appliances:

> "The typical urban home had four to six rooms for three persons. Amenities included running water, private toilet and bath, central heating (except in the South), gas or electric stove, and mechanical refrigerator. The rent for such a home was estimated by one study to be about $38 monthly" (Brown, 1994, p. 215).

Other Evidence on Quality Change

When we combine the Brown, Weston, and Census data, we are faced with a conflict between an improvement in quality characteristics involving electricity, heating, plumbing, and appliances, but a decline in the average number of rooms per unit. This decline is verified by Grebler-Blank-Winnick (1956, pp. 119-21), who display a special tabulation from the 1950 Census of Housing showing a decline from 4.76 rooms per urban and rural nonfarm dwelling unit for units built before 1919 to 4.26 rooms for units built after 1945. They argue convincingly that this decline understates the true decline because of conversions that created more units per multi-family building over the years between the construction date and the data source in 1950. They argue that, since conversions to increase the density of multi-family buildings occur mainly in older buildings, then the pre-1919 buildings were originally built with more rooms per unit than the 4.76 figure cited above. Overall, the authors conclude that this decrease in average dwelling size "was probably more than enough to compensate for the addition of new equipment and facilities since the twenties" (G-B-W, p. 121).

Quantifying Quality Change

To summarize our findings on quality change to this point, we found that quality attributes available in the AHS data but not available in the Weston or Census of Housing data contributed about 0.9 percent per year to explaining price change (Table 8

above). On balance the characteristics available for the pre-1970 Census years, primarily rooms per unit and age, exhibit a quality deterioration after 1975 due to increasing age. This result is highly suspect, because age does not increase nearly as much in the Census microdata (Table 11, line 3) as in the AHS data (Table 2, line 4). Quality change is also measured to occur at an annual rate of about 1.0 percent in the Census microdata for the decade 1960-70, but at a smaller rate after 1970.

The Weston analysis exhibits no net quality change between 1930 and 1960, because a decline in rooms per unit and an increase in age offsets the benefits of improved plumbing and reduced "dilapidation." But Weston does not include key aspects of quality improvement reported in the CES budget studies summarized by Brown, who documents a transition from 1918, when most tenant units lacked central heating, half lacked electricity, one-third or more lacked full plumbing facilities, and virtually none had electric appliances, to 1973 when central heating, electricity, full plumbing, and a refrigerator and stove were standard equipment in apartments.

How much were these quality improvements worth? Both the Weston data and the Census regressions estimate the value of full plumbing as increasing the log of rent by about 0.6. The AHS regressions for 1975-85 yield a coefficient of 0.8, while after 1985 the coefficient on plumbing is much lower, presumably because it had become almost universal. At least in principle the Weston quality change measures incorporate a plumbing effect back to 1930. If during 1918-1930 the extent of complete plumbing

increased roughly from 0.6 to 0.75, a coefficient of 0.6 would imply a quality improvement of 9 percent, or 0.75 percent per year during the 1918-30 interval.[27]

An analogy to the value of central heating can be taken from the example of central air conditioning, for which we have coefficients in the range of 0.11 to 0.18 in Table 3, averaging out at 0.15. Over the period 1975 to 2001, the percentage of units with central AC in the AHS sample increased from 15 to 42 percent, and this can be translated into an annual rate of improvement of quality of 0.16 percent per year.[28] It could be argued that the value of central heat was less than the value of air conditioning, since housing units were already heated, albeit inconveniently, before central heating became pervasive, whereas before the invention of residential air conditioning around 1950 people just sweltered. The convenience and cleanliness advantage of the transition from coal to fuel oil and natural gas raises the value of central heating, so let us consider a coefficient of 0.25. An increase in the percentage use of central heating from 15 percent in 1918 to 100 percent in 1973 would represent an annual rate of quality improvement of 0.39 percent per year.

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[27] A coefficient of 0.6 means that the presence of full plumbing compared to the absence of full plumbing raises the log of rent by 0.6. This full effect of 0.6 would occur if the presence of full plumbing went from zero to 100 percent. A 15 percentage point increase would be 15 percent of this, or 0.15 times 0.6, or 0.09.

[28] Following the procedure in the previous footnote, a complete conversion from 0 percent to 100 percent central AC would raise the log value of the average apartment by 0.15. The observed increase of 27 percentage points raised the log value by 0.15 times .27, or 0.041, and this occurred over 26 years for an annual rate of improvement of 0.041/26, or 0.16 percent per year.

It is more difficult to speculate about electrification. Once a rental unit had electricity, then households could bring lighting into the home for the cost of a few inexpensive light fixtures. Later on, as home appliances were invented and improved, homes with electricity had access to refrigerators and washing machines. The benefit of electricity must have been as great as that of central heating, say a coefficient of 0.25, implying that the increase in electrification from 50 percent in 1918 to 100 percent by 1950 represented an annual rate of quality change of another 0.39 percent per year.

Adding up only these three aspects of quality change, we have for 1918-30 0.75 for plumbing, 0.39 for heating, and 0.39 for electricity, for a sum of 1.53 per year. After 1930 there is no separate adjustment for plumbing, which is taken into account in Weston's analysis, but the heating and electricity contributions continue, adding up to 0.78. Gradually in the 1950s and 1960s the heating and electricity contributions die out but are replaced by other contributions of quality change, as indicated in our regression analysis of the Census and AHS data. Overall, there seems ample evidence to support a rate of quality improvement in rental apartments of 1.0 percent per year, with perhaps a greater rate of improvement in the first half of the twentieth century when the impact of indoor plumbing, electricity, the conversion to central heating and away from coal, and the inclusion of a refrigerator and a stove as standard equipment had their maximum effect. By coincidence, a completely independent analysis of the relationship between rent, age, and maintenance costs of commercial office buildings arrives at an estimated

rate of technical progress for structures of 1.0 percent per year (Gort, Greenwood, and Rupert, 1999, p. 225).

A Study of Apartment Rents in a Specific Locality

A final piece of long-term historical evidence on tenant rents comes from a project designed to collect at the local level in order to assess historical changes in the CPI for rent. This has the advantage that it allows us to control for many types of quality change discussed above, including type of heat, electrification, and plumbing equipment. Just as important, by its limitation to a single locality, the resulting index is free of the effects of changing regional and metropolitan location on average rents paid.

Evanston, Illinois, is the location for a pilot project to determine the feasibility of this kind of research.[29] Most important, data were readily available in the archives of the local suburban newspaper, which has published continuously since the 1920s. In addition, the housing stock in Evanston combines aspects of city and suburb, serving as a microcosm for a range of different types of apartments and houses. The closest northern suburb of Chicago along Lake Michigan, Evanston had a population in 2000 of about 72,000. The population ranges from very wealthy to poor, and homes range from mansions to tiny houses and modest apartments. The city was founded in the mid-1800s and was well established by 1925, the year for which our data begin. These

[29] This is a summary of Gordon and Mandelkern (2001). See also Mandelkern (2001).

factors allowed us to collect data on tenant rent and prices for a variety of living units over the past 75 years.

The first phase of our research involved collecting apartment prices over the interval 1925-99 from classified advertisements in the *Evanston Review*, a weekly local newspaper. In order to control for quality change, data were collected on apartments for which the advertisement provided detailed descriptions, including number of rooms and bathrooms, proximity of public transportation, schools, and/or shopping, parking, heat (type and whether included in rent), air conditioning (first appearing in the 1960 ads), and whether anything else was included (such as appliances). We noted other descriptive attributes, such as wood floors or garden view, and terms such as "luxury building." Because of space limitations, each ad did not contain information for each of the mentioned categories. When possible we chose buildings that listed the specific address, and only considered unfurnished apartments. Data were collected for every five years from 1925 to 1999. September was chosen as the month for each sample because many buildings advertise at this time, possibly to attract returning college students, although August and October were also used as a supplement if the September issues did not contain enough data. Our ideal was to find the same building addresses repeated from sample to sample. In some instances this was possible, and a "Specific Address" index was compiled. However, for several time periods, insufficient data containing specific address information were available. This was particularly a

problem for 1945 and 1950, when there was a housing shortage. This problem affected comparisons for the surrounding periods.

To analyze our data, we matched apartments as closely as possible over each five-year interval. When possible, we matched apartments in the same building and with the same description (especially number of rooms and bathrooms), so that our resulting rent index is equivalent to the "matched model" indexes used in previous research on durable goods, apparel, and computers. We were able to find between three and eleven exact address matches for each interval other than 1925-1930, 1940-1955, and 1965-1970. Because of the small number of matches in some instances and the lack of information in others, we filled in the gaps in the "Specific Address" index by borrowing from the Median Index (discussed below). The five-year change in rent for each matching apartment was averaged together with equal weights, yielding a log rent change for each five year period. This series of changes was then cumulated into the "Specific Address" rent index, which is displayed and compared with the CPI for rent in Table 13.

To supplement the first index, we grouped apartments into categories based on the number of rooms for 3, 4, 5, and 6 room apartments. To make the sample as accurate as possible, we included as many apartments for which we could find data (generally at least ten, but fewer for the intervals previously mentioned for which data were limited). Starting with the 1960 ads, some ads contained information about the

number of bedrooms rather than the number of total rooms. This alternative method of counting rooms extended through 1999 and became the norm in the ads. It was not clear whether an apartment listed only as a "1 bedroom" was better averaged with the "3 room" or "4 room" categories. However, many ads included wording such as "1 bedroom, 4 room apartment" during the transitional years. By using this transitional information and by comparing listed rents, we decided to convert between the listings on the following scale: 1 bedroom=4 rooms, 2 bedroom=5 rooms, 3 bedroom=6 rooms.

After compiling the mean data for 3, 4, 5, and 6 room apartments for 1925-1999, we used the same raw data to compile several other indices. In the years from World War II to the present, there were sometimes insufficient listings for 3 room and 6 room apartments. To make up for this, we compiled an index including only 4 and 5 room apartments (for which data were plentiful). To compare with our other indices, we also compiled an index using the median, instead of the mean, for 3, 4, 5, and 6 room apartments. Since the median, mean and the 4-5 room indexes were very close, Table 13 displays only the Specific Address index and the Median index for 3,4,5, and 6 room apartments.

Differences between the CPI and the two new apartment rent indexes are summarized at the bottom of Table 1, which displays average annual growth rates over the intervals 1925-50, 1950-75, and 1975-99. Differences between the two new rent indexes are relatively minor, and both display growth rates faster than that of the CPI in

all three periods. The difference for the Specific Address index is 1.78 percent per year in 1925-50, 0.98 percent per year in 1950-75, and a much smaller 0.29 in 1975-99. The average annual growth rate for the entire period is 1.03 percent faster than the CPI for the Specific Address index and 1.23 percent faster for the Median index.

The primary weakness in the new rent indexes is the potential for unmeasured quality change. Presumably the Specific Address index is more accurate than the Median index (the latter is used to proxy the former for those time intervals when insufficient Specific Address information was available). The most important types of quality differences among apartments are carefully controlled in the new indexes, especially number of rooms, bathrooms, location, and presence or absence of air conditioning. There may be some downward bias, because the indexes do not make any explicit allowance for age, and many of the apartments were new in the 1920s and more than 70 years old in 1999. While this source of bias was corrected after 1988, it has been estimated that the downward bias for aging in the CPI prior to 1988 is 0.3 percent per year (Randolph, 1988). Since our new indexes share with the CPI the method of following the same apartments over time, they share both the aging bias and also the lack of explicit allowance for renovations and modernization that may largely or entirely offset the aging bias.

Overall for the 1925-75 period, the difference between our two indexes and the CPI are 1.38 and 1.49 percent, respectively, and this is smaller than the 1918-73

difference for mean rents from Brown (1.88 percent), or the Weston Census-based mean rent data (2.12 percent). Since there is substantial control for quality change and total control for regional effects, one could argue that the smaller difference between the CPI and Evanston indexes provides an indirect measure of the impacts of regional and quality effects. This conclusion would be a bit rash, of course, because a small city does not replicate the United States, and we need at a minimum to check for the significance of any differences in apartment rents in the national CPI and the CPI for the Chicago area.

Conclusion

We have examined a wide variety of data on the historical behavior of tenant rents over the entire history of the CPI from 1914 to 2001. We began from the hypothesis that the CPI is biased downward over its history and have linked that hypothesis to complementary work on CPI methodology by Crone, Nakamura, and Voith (CNV, 2003a) that traces the downward bias primarily to nonresponse by tenants who moved just as rents were raised. CNV pinpoint the period of greatest bias as 1942 to 1988, and in our data the CPI rises less rapidly than mean or median contract rent at an annual rate of exactly 2.00 percent between 1940 and 1987.[30] Our initial examination of data finds that the 2 percent difference extends to other time periods and data sources. The difference was much less between 1914 and 1930 and after 1985.

[30] See Table 1, where we take for 1940 the average of the values in columns (3) and (4).

Any difference, no matter how large, does not imply a bias in the CPI if quality change were sufficiently rapid. We have gathered a rich set of data sources to assess the importance of quality change in rental housing units over our long historical period of study. We begin with a hedonic regression analysis on a large set of panel data from the American Housing Survey (AHS) covering 1975-2001. Our primary focus is on understanding the contribution of quality characteristics to differences between estimated hedonic price indexes and raw unadjusted changes in apartment rent. We segregate the explanatory variables into traditional quality measures (number of rooms, age, and presence or absence of full plumbing), nontraditional quality characteristics, and variables for regional location and government subsidies that do not themselves measure quality. We find that the traditional quality measures contribute little, or even a negative amount, to the explanation of price change, primarily because of large increases in the age of apartment units that may be spurious. The nontraditional quality characteristics consistently contribute about 0.9 percent per year to the explanation of price change.

The major challenge in the paper is to assess the importance of quality change prior to the beginning of the AHS data in 1975. We create an overlap measure of quality-adjusted price change from Census of Housing microdata for 1960-90, giving us a chance to run a regression with 750,000 observations. The Census data have the defect that they are limited to the traditional quality measures, and these yield an estimated

rate of quality increase of 1.0 percent per year for 1960-70 but negligible rates after that, at least in part because of the influence of the increasing age of rental units. Also available for the pre-1975 period is Weston's study based on Census data for 1930-70. We extract a price and quality index from his data, and these indicate virtually no quality change between 1930 and 1960 and then a rapid rate of about 1.50 percent per year for 1960-70. Aspects of the Census data look more plausible to us for the 1960-70 period, and we prefer the Census quality change estimate of 1.0 percent for that decade.

For earlier periods we rely on two types of analysis. First, we stitch together data on the diffusion of important quality attributes of rental units, including plumbing, heating, and electrification, over the period 1918-73. Applying guesstimates about the value of these attributes based in part on the post-1960 hedonic regressions, we conclude that quality change in the 1918-73 period must have been substantial. Our guesstimates yield larger estimates of the growth rate of quality as we move further back, because the impact of indoor plumbing was largely completed by 1935 and that of electrification by 1950. These factors could contribute annual rates of increase of quality change of as much as 1.6 percent per year for 1918-30, 0.8 percent for 1930-50, and 0.4 percent for 1950-73.

Our final piece of evidence is based on a study of rents in a single local community, Evanston IL, covering the period 1925-99. Here we control for location effects by limiting the project to a single small area and control for such quality

attributes as number of rooms, number of bathrooms, type of building, heating, and air conditioning. One of our indexes is analogous to repeated-sales indexes of housing prices (Case and Shiller, 2003), in that it measures changes in rent for apartments having the same specific street address over time. This study yields a difference between the CPI and the two Evanston indexes of 1.38 and 1.49 percent per year for 1925-75, about 0.5 to 0.6 percent less than the difference between the CPI and contract rent. To the extent that it successfully controls for quality change in most of the attributes that enter hedonic regressions, the Evanston index may provide an indirect estimate that quality change proceeded at less than 1.0 percent per year over the 1925-75 period.

Our overall conclusion differs by period. Quality change was sufficiently important in the early years, say 1914-30, that the CPI is probably upward biased in that period. Over 1930-87, when the difference in growth rates between the CPI and mean rent is about 2 percent, we conclude that roughly half of that difference represents quality change and the remaining half represents a downward bias in the CPI.[31] Our reliance on a wide variety of evidence on types of quality change and their importance, while leaving the outcome still uncertain, at least in our view narrows the range of possibilities regarding the history of CPI bias for rental shelter.

[31] Hence we reject the CNV (2003a) conclusion of a bias of roughly 1.8 percent between 1940 and 1985 as excessive and making insufficient allowance for quality change.

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Data Appendix

American Housing Survey, AHS

This paper uses 14 cross-sections of American Housing Survey[32] microdata courtesy of the Inter-University Consortium for Political and Social Research, and the U.S. Department of Housing and Urban Development. We would also like to thank Theodore Crone of the Philadelphia Federal Reserve Bank for providing AHS datasets which were used in preliminary stages of this investigation. The AHS provides detailed cross-sectional microdata in two survey forms, metropolitan and national. The metropolitan survey is conducted during even years and the national survey in odd. This study makes exclusive use of the national survey. Each year a consistent basic panel is sampled and units are followed year to year whenever possible. Panels are updated for new construction in areas where building permits are required, and units missed in the reference census year. Interviews were done in person on paper form until 1997 when laptops were introduced to enhance speed and accuracy in data collection. The resulting datasets provide a robust set of characteristic and quality variables that are well suited for the estimation of hedonic price equations.

The original 1973-83 AHS panel was based on the 1970 Census of Housing. In 1985 the panel and survey form were redesigned to improve data quality and

[32] Before 1983 the AHS was known as the Annual Housing Survey. We use only the new title in this work.

incorporate the 1980 Census results. This basic 1985 panel has been used every year since.

Data Quality Issues in the American Housing Survey

The most important variable for our analysis is clearly rent. The AHS records contract rent in a continuous fashion from $0 up to a different topcode in each year. Although this will inevitably cut off the tail of the distribution, it is unlikely to adversely influence our results. Units in the highest price echelon are likely to have highly specialized attributes which cannot be recorded in basic characteristic data and thus cannot be priced by a traditional hedonic approach.

The year a unit was built is not continuous in the AHS. Irregularly shaped bins are used in place of discreet years. The 1973-1983 panel has 6 such bins and the 1985-present panel has 9. Our calculations estimate a unit's approximate age using the midpoint of each bin. The last bin is unbounded and creates a catchall for older units. End bins were problematic; their final coding treats the end bins as if they were the same size as the earlier bins. The approximate age variable cannot be viewed as an ideal measure of mean unit age. While the first panel was in use between 35-45% of all rental units fell into the end bin, making age estimates very susceptible to the approximation. The problem is ameliorated in the 1985-present panel by the introduction of more bins covering older build dates.

While generally of very high quality, the AHS data occasionally suffers when a malformed survey question creates double counting or, oppositely, underestimation. For example, before 1984 respondents were asked a single question asking for the total count of rooms. This caused acute underreporting of rooms because of the dubious definition for exactly what constituted a room. When the survey was redesigned this was established and the current counts are more accurate.

Differences between the 1973-1975 and 1985-present surveys make some variables non-comparable. Those describing a unit's location relative to a city or metro area changed due to the methods used to assign status as within a metropolitan area. Privacy concerns previously disallowed identification in any area with a population under 250,000 persons. This rule was relaxed to any area under 100,000. Similarly, data for plumbing was made useless in the 1985 data when a malformed survey question unreliable answers. This resulted in an unreasonable drop (and subsequent rise upon correction) in the quantity of units with incomplete plumbing facilities.

Also particularly problematic in the first panel are the data on neighborhood characteristics. Respondents were asked if certain attributes – for example: crime, littler, noise – were earmarked as bothersome instead of merely present, thereby making the measurement of these already difficult to measure characteristics near impossible. Surveyors were also instructed to collect some neighborhood variables for certain kinds of dwelling units. This makes comparisons for variables such as having

crime, littler, and noise problems unreliable. Our work includes these variables, but focuses more on unmeasured quality change due to basic characteristic variables. CNV (2003b) came to a similar conclusion with respect to the AHS's coverage of these variables.

Decennial Census Data Microdata

To make comparisons to older measures of quality change and specifically Rafael Weston's PhD thesis, our study makes use of Census of Housing microdata files spanning from 1960-1990. These data are used courtesy of the University of Minnesota at Minneapolis's Historical Census Project. The Integrated Public use Microdata Series[33], provides easily accessible datasets and codebooks, and maintains information on the comparability of each variable in their series over time. Compared to the AHS, census data does not contain nearly as robust a set of variables and is thus less useful for understanding the breakdown of quality change over time. The longer time sample for census data allows us to extend the analysis into history with relative ease.

Caveats For the IPUMS

Rent and age information is encoded into discrete bins similarly to the AHS's build-year variable. This creates artificially low variability in the continuous estimated rent and age variables used in the hedonic price regressions. This is responsible for the

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[33] Steven Ruggles and Matthew Sobek et al.
Integrated Public Use Microdata Series: Version 3.0
Minneapolis: Historical Census Projects,
University of Minnesota, 2003

very high level explained variation seen in each of the Census regressions. Correspondingly these data also suffer from the same top and bottom code problems thus eliminating the tails of the distribution as discussed above. They are similarly not the ideal basis for measures of implied quality change but will perform adequately well.

TABLE 1
Alternative Measures of Monthly Rental Expenditure, 1914-2001

	CPI for Rent, 1982-84 = 100 (1)	GBW Mean Gross Rent (2)	Weston Mean Gross Rent (3)	CNV Median Contract Rent (4)	Census of Housing Mean Contract Rent (5)	AHS Mean Contract Rent (6)	Brown CES Budget Study Rent "Salaried" (7)	(8)	(9)
1914	21.0	19.23							
1918	21.5						20.67		
1920	27.4	28.37							
1925	34.6	33.91							
1930	31.2	30.49	33.22	26.26					
1935	21.4	28.44					30.17		
1940	23.7		30.89	20.86					
1950	29.7		46.08	35.09			41.00		
1960	38.7		74.92	59.62	62.31				
1970	46.5		115.80	91.65	98.95				
1973	52.5						141.67		
1975	58.0					135.20			
1977	64.8			159.33		159.33			
1979	74.3					188.97			
1980	80.9				216.04				
1981	87.9					241.57			
1983	100.1					271.12			
1985	111.8			337.98		314.50			
1987	123.1					344.11			
1988	127.8						549.25		
1989	132.8					394.76			
1990	138.4				410.03				
1991	143.3					425.61			
1993	150.3					456.02			
1995	157.8			474.84		494.76			
1997	166.7					513.80			
1999	177.5					579.46			
2001	192.1			589.32		627.94			
	Growth Rates							**Differences**	
1914-30	2.64	3.07						-0.43	
1918-73	1.62						3.50	-1.88	
1930-70	1.00		3.12	3.13				-2.12	-2.13
1960-90	4.25				6.28			-2.03	
1973-88	5.93						9.03	-3.10	
1977-85	6.82			9.40		8.50		-2.58	-1.68
1985-95	3.45			3.40		4.53		0.05	-1.08
1995-2001	3.28			3.60		3.97		-0.32	-0.69

Sources: See Next Page

Sources for Table 1 by column:

1. CPI for rent, 1982-84 = 100, BLS web site, series CUUR0000SEHA, "U. S. City Average, Rent of Primary Residence, 1982-84 = 100."

2. Grebler-Blank-Winnick (1956). Total nominal expenditures on aggregate rental expenditures from Table I-1 on p. 407, averaged together as appropriate. For instance, 1914 is based on the line labeled "1909-19", 1920 is the average of the lines labeled "1909-19" and "1919-29", etc. Number of nonfarm households from Table 23 on p. 82. Mean Gross Rent is aggregate rental expenditures divided by total nonfarm households.

3. Weston (1972), mean rents calculated from Tables 3-3 and 3-4. Table 3-3 contains the number of units cross-classified by type. Table 3-4 contains rents for each of the types. The mean rent was calculated by multiplying each cell from those tables to yield rental revenue, summed to equal total revenue in each year, and then divided by the total number of rental units.

4. Calculated from CNV (Table 11), starting with our 1977 value in column (5) from the AHS data, and working forward and backward by calculating the CNV annualized growth rates into changes in levels using antilogarithms (the exponential function). This conversion introduces an unknown degree of error (to be checked subsequently with CNV), because the growth rates calculated by CNV in their appendix 2 (where both levels and growth rates of the CPI-W are shown) are not accurate calculations of compound growth rates using natural logs.

5. Integrated Public Use Microdata series, University of Minnesota, www.ipums.org.

6. Mean of all observations in AHS regression data. For issues involved in sources and manipulation of AHS regression data, see Data Appendix.

7. Brown (1994), for the five years shown, the source tables and page numbers are 1918, Table 3.6A, p. 62; 1935, Table 4.8, p. 127; 1950, Table 5.10, pp. 212-13; 1973, Table 6.8A, pp. 294-5; 1988, Table 7.8A, pp. 392-3.

TABLE 2

Mean Values, AHS Data

Variable	1975	1985	1993	2001
Rent	135.20	313.22	453.10	627.94
Unit Square Feet	N/A	1058.68	1075.52	N/A
Bedrooms	1.84	1.88	1.92	1.94
Other Rooms	2.24	2.39	2.43	2.36
Approximate Age	25.22	30.81	37.10	48.54
		Percentages		
Northeast Region	25.68	24.04	23.37	22.33
Midwest Region	23.25	23.15	21.51	20.88
South Region	30.50	30.09	31.17	31.70
West Region	20.57	22.73	23.95	25.09
Urban Area	57.76	89.66	87.22	87.25
Has Multiple Bathrooms	6.57	15.51	15.20	17.78
Has Central Air Conditioning	14.99	26.93	33.75	42.08
Interaction: Central Air & NE	5.05	8.74	9.96	13.85
Interaction: Central Air & MW	13.07	23.48	29.48	39.01
Interaction: Central Air & S	28.33	50.04	60.48	72.58
Interaction: Central Air & W	9.77	19.06	26.03	31.21
Has Dishwasher	N/A	28.24	34.64	N/A
Has Fireplace	N/A	11.20	12.89	N/A
Has Porch	N/A	56.92	61.82	N/A
Has Elevator	7.89	9.80	9.36	N/A
Garage included in Rent	N/A	27.98	29.40	N/A
Lacks Piped Hot or Cold Water	N/A	0.68	0.31	N/A
Incomplete Plumbing Fixtures	4.67	1.20	1.75	2.05
No Sewer Connection	16.43	9.24	8.94	6.38
Visible Wiring	N/A	3.35	2.54	N/A
Signs of Rodents	11.87	7.52	4.73	15.00
Holes in Floors	3.67	2.92	2.14	1.75
Cracked Walls	N/A	10.76	8.08	N/A
Noise Problem	N/A	11.22	12.09	14.21
Litter Problem	N/A	4.31	3.89	15.16
Neighborhood Bothersome	N/A	40.26	41.67	N/A
Public Housing	6.83	7.36	6.74	N/A
Rent is Federally Subsidized	1.68	4.37	4.68	N/A
Rent is Locally Subsidized	N/A	1.46	1.65	N/A

TABLE 3

Parameter Estimates, AHS Data

Variable	1975-85	1985-95	1995-01
Intercept	4.82 **	5.00 **	5.61 **
ln(Unit Square Feet)		0.04 **	
ln(Bedrooms)	0.14 **	0.09 **	0.11 **
ln(Other Rooms)	0.12 **	0.10 **	0.21 **
ln(Approximate Age)	-0.16 **	-0.07 **	-0.06 **
Northeast Region	0.27 **	0.37 **	0.30 **
Midwest Region	--	--	--
South Region	-0.28 **	-0.21 **	-0.25 **
West Region	0.22 **	0.32 **	0.36 **
Urban Area	0.18 **	0.28 **	0.26 **
Has Multiple Bathrooms	0.29 **	0.17 **	0.28 **
Has Central Air Conditioning	0.18 **	0.11 **	0.16 **
Interaction: Central Air & NE	0.08 **	-0.06 **	-0.02
Interaction: Central Air & MW	--	--	--
Interaction: Central Air & S	0.25 **	0.18 **	0.20 **
Interaction: Central Air & W	-0.18 **	-0.22 **	-0.21 **
Has Dishwasher		0.16 **	
Has Fireplace		0.10 **	
Has Porch		-0.04 **	
Has Elevator	0.14 **	0.21 **	
Garage included in Rent		0.09 **	
Lacks Piped Hot or Cold Water		-0.89 **	
Incomplete Plumbing Fixtures	-0.80 **	-0.11 **	-0.05 **
No Sewer Connection	-0.10 **	-0.10 **	-0.06 **
Visible Wiring		-0.06 **	
Signs of Rodents	-0.09 **	-0.04 **	-0.03 **
Holes in Floors	-0.11 **	-0.05 **	-0.05 **
Cracked Walls		-0.02 **	
Noise Problem		0.02 **	
Litter Problem		-0.03 **	-0.07 **
Neighborhood Bothersome		0.02 **	
Public Housing	-0.66 **	-0.65 **	
Rent is Federally Subsidized	-0.43 **	-0.28 **	
Rent is Locally Subsidized		-0.13 **	
1977 Time Dummy	0.22 **		
1979 Time Dummy	0.29 **		
1981 Time Dummy	0.49 **		
1983 Time Dummy	0.63 **		
1985 Time Dummy	0.82 **		
1987 Time Dummy		0.10 **	
1989 Time Dummy		0.20 **	
1991 Time Dummy		0.31 **	

1993 Time Dummy		0.36 **	
1995 Time Dummy		0.45 **	
1997 Time Dummy			0.09 **
1999 Time Dummy			0.18 **
2001 Time Dummy			0.25 **
Adjusted R^2	0.55	0.41	0.26
DoF	42210	52169	54422
SEE	0.53	0.51	0.50
SSR	11835	13424	13674

TABLE 4

Effect of Stripping Sets of Variables, AHS Data, 1975-85

Variable	Full Specification	Weston Analysis Specification	Weston + Housing Subsidy Vars	Removed Quality Variables	Year Only
Intercept	4.82 **	4.76 **	4.94 **	4.43 **	4.49 **
ln(Bedrooms)	0.14 **	0.16 **	0.16 **		
ln(Other Rooms)	0.12 **	0.22 **	0.17 **		
ln(Approximate Age)	-0.16 **	-0.19 **	-0.23 **		
Northeast Region	0.27 **	0.25 **	0.27 **	0.20 **	
Midwest Region	--	--	--	--	
South Region	-0.28 **	-0.20 **	-0.20 **	-0.20 **	
West Region	0.22 **	0.22 **	0.19 **	0.24 **	
Urban Area	0.18 **	0.19 **	0.23 **	0.22 **	
Has Multiple Bathrooms	0.29 **				
Has Central Air Conditioning	0.18 **				
Interaction: Central Air & NE	0.08 **				
Interaction: Central Air & MW	--				
Interaction: Central Air & S	0.25 **				
Interaction: Central Air & W	-0.18 **				
Has Elevator	0.14 **				
Incomplete Plumbing Fixtures	-0.80 **	-0.85 **	-0.88 **		
No Sewer Connection	-0.10 **				
Signs of Rodents	-0.09 **				
Holes in Floors	-0.11 **				
Public Housing	-0.66 **		-0.71 **	-0.57 **	
Rent is Federally Subsidized	-0.43 **		-0.44 **	-0.33 **	
1977 Time Dummy	0.22 **	0.18 **	0.21 **	0.20 **	0.17 **
1979 Time Dummy	0.29 **	0.35 **	0.36 **	0.36 **	0.35 **
1981 Time Dummy	0.49 **	0.55 **	0.56 **	0.56 **	0.58 **
1983 Time Dummy	0.63 **	0.68 **	0.71 **	0.70 **	0.68 **
1985 Time Dummy	0.82 **	0.91 **	0.92 **	0.95 **	1.08 **
Adjusted R^2	0.55	0.45	0.52	0.36	0.24
DoF	42210	42221	42219	44091	44097
SEE	0.53	0.59	0.55	0.64	0.69
SSR	11835	14551	12815	17887	20964

TABLE 5

Effect of Stripping Sets of Variables, AHS Data, 1985-95

Variable	Full Specification	Weston Analysis Specification	Weston + Housing Subsidy Vars	Removed Quality Variables	Year Only
Intercept	5.00 **	5.23 **	5.42 **	5.18 **	5.57 **
ln(Unit Square Feet)	0.04 **				
ln(Bedrooms)	0.09 **	0.16 **	0.16 **		
ln(Other Rooms)	0.10 **	0.28 **	0.21 **		
ln(Approximate Age)	-0.07 **	-0.15 **	-0.17 **		
Northeast Region	0.37 **	0.34 **	0.35 **	0.28 **	
Midwest Region	--	--	--	--	
South Region	-0.21 **	-0.06 **	-0.08 **	-0.01 *	
West Region	0.32 **	0.36 **	0.31 **	0.36 **	
Urban Area	0.28 **	0.37 **	0.39 **	0.34 **	
Has Multiple Bathrooms	0.17 **				
Has Central Air Conditioning	0.11 **				
Interaction: Central Air & NE	-0.06 **				
Interaction: Central Air & MW	--				
Interaction: Central Air & S	0.18 **				
Interaction: Central Air & W	-0.22 **				
Has Dishwasher	0.16 **				
Has Fireplace	0.10 **				
Has Porch	-0.04 **				
Has Elevator	0.21 **				
Garage included in Rent	0.09 **				
Lacks Piped Hot or Cold Water	-0.89 **				
Incomplete Plumbing Fixtures	-0.11 **	-0.24 **	-0.26 **		
No Sewer Connection	-0.10 **				
Visible Wiring	-0.06 **				
Signs of Rodents	-0.04 **				
Holes in Floors	-0.05 **				
Cracked Walls	-0.02 **				
Noise Problem	0.02 **				
Litter Problem	-0.03 **				
Neighborhood Bothersome	0.02 **				
Public Housing	-0.65 **		-0.75 **	-0.73 **	
Rent is Federally Subsidized	-0.28 **		-0.34 **	-0.31 **	
Rent is Locally Subsidized	-0.13 **		-0.19 **	-0.20 **	
1987 Time Dummy	0.10 **	0.13 **	0.13 **	0.11 **	0.09 **
1989 Time Dummy	0.20 **	0.25 **	0.25 **	0.23 **	0.23 **
1991 Time Dummy	0.31 **	0.37 **	0.37 **	0.34 **	0.32 **
1993 Time Dummy	0.36 **	0.45 **	0.45 **	0.40 **	0.40 **
1995 Time Dummy	0.45 **	0.54 **	0.54 **	0.49 **	0.50 **
Adjusted R^2	0.41	0.24	0.32	0.25	0.07
DoF	52169	78811	78808	82499	82456
SEE	0.51	0.58	0.55	0.58	0.65
SSR	13424	26898	23899	27601	34317

TABLE 6

Effect of Stripping Sets of Variables, AHS Data, 1995-2001

Variable	Full Specification	Weston Analysis Specification	Weston + Housing Subsidy Vars	Removed Quality Variables	Year Only
Intercept	5.61 **	5.83 **	N/A	5.69 **	6.06 **
ln(Bedrooms)	0.11 **	0.18 **			
ln(Other Rooms)	0.21 **	0.27 **			
ln(Approximate Age)	-0.06 **	-0.15 **			
Northeast Region	0.30 **	0.28 **		0.22 **	
Midwest Region	--	--		--	
South Region	-0.25 **	-0.05 **		0.01	
West Region	0.36 **	0.32 **		0.34 **	
Urban Area	0.26 **	0.33 **		0.26 **	
Has Multiple Bathrooms	0.28 **				
Has Central Air Conditioning	0.16 **				
Interaction: Central Air & NE	-0.02				
Interaction: Central Air & MW	--				
Interaction: Central Air & S	0.20 **				
Interaction: Central Air & W	-0.21 **				
Incomplete Plumbing Fixtures	-0.05 **	-0.09 **			
No Sewer Connection	-0.06 **				
Signs of Rodents	-0.03 **				
Holes in Floors	-0.05 **				
Litter Problem	-0.07 **				
1997 Time Dummy	0.09 **	0.11 **		0.05 **	0.04 **
1999 Time Dummy	0.18 **	0.22 **		0.15 **	0.15 **
2001 Time Dummy	0.25 **	0.29 **		0.23 **	0.22 **
Adjusted R^2	0.26	0.19		0.11	0.02
DoF	54422	54431		55826	55830
SEE	0.50	0.52		0.55	0.58
SSR	13674	14823		16813	18563

TABLE 7

Effects of Stripping Sets of Variables, Census Microdata, 1960-1990

Variable	Census Hedonic	Quality Variables Removed	Year Only
Intercept	4.43 **	3.90 **	3.98 **
ln(Bedrooms)	0.11 **		
ln(Other Rooms)	0.15 **		
ln(Approximate Age)	-0.19 **		
Northeast Region	0.19 **	0.15 **	
Midwest Region	--	--	
South Region	-0.10 **	-0.07 **	
West Region	0.25 **	0.27 **	
Incomplete Plumbing Fixtures	-0.71 **		
1970 Time Dummy	0.36 **	0.46 **	0.47 **
1980 Time Dummy	1.15 **	1.27 **	1.28 **
1990 Time Dummy	1.78 **	1.89 **	1.89 **
Adjusted R^2	0.65	0.59	0.57
DoF	708246	750629	750632
SEE	0.49	0.53	0.57
SSR	170047	211097	224586

Sources:

Census microdata extract courtesy of the IPUMS project <http://www.ipums.umn.edu/>.

TABLE 8

Annualized Growth Rates by Index

Time	CNK Box-Cox Hedonic Specification (1)	Full Specification (2)	Weston Analysis Specification (3)	Weston + Housing Subsidy Variables (4)	Removed Quality Variables (5)	Year Only (6)	Mean Rent (7)	CPI (8)
1960-1990	N/A	5.92	N/A	N/A	6.29	6.31	6.28	4.25
1975-1985	9.04	8.24	9.07	9.20	9.51	10.77	8.44	6.56
1985-1995	4.66	4.48	5.36	5.42	4.86	4.96	4.53	3.45
1995-2001	N/A	4.13	4.87	N/A	3.81	3.67	3.97	3.28

Sources by coumn:

1. Crone-Nakamura-Voith (2003b, Table 5)

2-6. AHS , IPUMS Census Microdata Hedonic Indexes, see Tables 4-7.

7. AHS, IPUMS Census Microdata, see Table 1

8. BLS

TABLE 9

Mean Gross Rent and Two Price Indexes from Weston's Data, 1930-70

	Mean Gross Rent	Weston Price Index	Tornqvist Index from Weston Data	Implied Quality Index from Weston	Implied Quality Index from Tornqvist
1930	33.22	100.0	100.0	100.0	100.0
1940	30.89	97.4	98.3	95.4	94.6
1950	46.08	149.4	146.6	92.8	94.6
1960	74.92	222.4	229.7	101.4	98.2
1970	115.80	292.2	305.5	119.3	114.1
Annual Growth Rates					
1930-40	-0.73	-0.26	-0.17	-0.47	-0.56
1940-50	4.00	4.28	4.00	-0.28	0.00
1950-60	4.86	3.98	4.49	0.88	0.37
1960-70	4.35	2.73	2.85	1.63	1.50
1930-70	3.12	2.68	2.79	0.44	0.33

Sources: First and third columns from Weston (1972), Tables 3-2 and 3-3.
Second column from Weston (1972), Table 5-1.

TABLE 10

Weston Quality Attributes

	1930	1940	1950	1960	1970
Age					
0-10	0.30	0.11	0.15	0.17	0.20
>10	0.70	0.89	0.85	0.83	0.80
Rooms					
1-2	0.12	0.17	0.18	0.15	0.06
3-4	0.33	0.41	0.52	0.53	0.32
5-6	0.37	0.33	0.26	0.28	0.44
>6	0.18	0.08	0.04	0.04	0.18
Mean*	4.65	4.13	3.81	3.91	4.89
Condition					
Not Dilapidated	0.83	0.85	0.90	0.94	0.97
Dilapidated	0.17	0.15	0.10	0.06	0.03
Plumbing					
With All	0.57	0.64	0.68	0.82	0.93
Lacking	0.43	0.36	0.32	0.18	0.07
Wgtd. Mean of Rent Ratio**	1.96	2.07	1.58	1.79	1.76

*calculated on midpoints of each bin, 7 was used for the last bin.

** mean ratio of rent for a unit with proper plumbing to one without, weighted by quantity.

TABLE 11

Mean Values, Census Microdata

Variable	1960	1970	1980	1990
Rent	62.31	98.95	216.04	410.03
Bedrooms	1.72	1.78	1.77	1.89
Other Rooms	2.21	2.21	2.26	2.25
Approximate Age	23.90	21.59	23.70	26.26
		Percentages		
Northeast Region	31.55	29.44	26.36	22.42
Midwest Region	24.57	23.51	22.27	20.64
South Region	27.12	27.11	28.23	31.16
West Region	17.16	19.95	23.15	25.36
Incomplete Plumbing Fixtures	17.78	6.06	0.92	0.74

TABLE 12
Data on Characteristics of Rental Units and All Dwelling Units, 1918-73

	Sources			Percentages			
	Rental or All Units?	Source Table	Source Page	1918	1935	1950	1973
Rooms	R	3.6B, 4.8	62,127	5.3	5.2		
Percent of Renters in Houses	R	3.6B, 4.8	62,127	64	55		
Electrification, Urban and Nonfarm Rural	A	HS	S73	47.4	83.9	96.6	
Heating							
Rooms Equipped for Heating	R	3.6B	62	55			
Warm-air Furnaces	A		126		31		
Central Heating	A						78
Plumbing							
With Bathroom	R	3.6B	62	64			
With Inside Water Closet	R	3.6B	62	78			
With hot running water, flush toilet, and electricity	A	4.8	127		80		
With bathroom, hot running water, flush toilet, and "not dilapidated"	A	5.1	212-3			84	
No Bathtub or Shower	R		127		28		
No Indoor Toilet	R		127		20		
Lacking Full Plumbing	A		298			34	3

Notes: Any data referring only to rental units ("R") refers to the average of wage earners and salaried workers. "HS" refers to the Historical Statistics volume cited in the references.

TABLE 13

Evanston Apartment Rent Indexes and CPI, 1925 = 100

	CPI for Rent	Specific Address Index	Median Index	Number of Observations: Address Index	Number of Observations: Median Index
1925	100.0	100.0	100.0	N/A	16
1930	90.3	122.7	119.8	10	16
1935	61.9	62.2	73.3	10	37
1940	68.7	82.1	84.7	6	35
1945	71.9	108.3	114.2	N/A	N/A
1950	86.1	134.5	143.8	N/A	9
1955	103.1	158.9	169.6	N/A	25
1960	112.1	155.9	178.9	6	28
1965	118.5	154.9	177.3	7	23
1970	134.6	232.3	257.8	N/A	16
1975	167.9	335.6	355.0	3	22
1980	234.2	494.5	504.9	3	23
1985	320.2	695.9	694.6	5	20
1990	395.4	846.8	920.8	11	29
1995	450.6	955.7	996.8	12	42
1999	506.9	1087.1	1257.6	10	26
Annual Growth Rates					
1925-50	-0.598643	1.1855761	1.453013		
1950-75	2.6714366	3.6574231	3.6147774		
1975-99	4.6039383	4.8972871	5.2701776		
1925-75	1.0363968	2.4214996	2.5338952		
1925-99	2.1934372	3.2244577	3.4213382		