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Downward Bias in the Most Important CPI Component
The Case of Rental Shelter, 1914–2003

Robert J. Gordon and Todd vanGoethem

6.1 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 gross domestic product (GDP).[1]

The high-water mark of widespread belief in the pervasiveness of upward bias in the CPI may have been reached on December 4, 1996, the re-

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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.

lease date of the Boskin Commission Report.[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 and Moses 1997). Second, the report appeared in a period of rapid improvement in the CPI, particularly in its treatment of substitution 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 1995–1996, may not be applicable to previous historical periods.

6.2 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's (1997) seminal paper on the history of the price of light. Hulten's point implies that the 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 (2004) 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 apparel, shelter, or 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 is upward biased for the entire twentieth century, as Gordon (1990) showed for the period 1947–1983, then some other major component of the CPI must have been downward biased. This paper assesses the extent of a downward bias for rental shelter housing, and a companion paper (Gordon 2004) examines new evidence showing a downward bias for apparel.[3] This set of research results finding

2. The Boskin conclusion was that, as of 1995–1996, 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).

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 1994, table 3.9, 78).

upward bias for some products and downward bias for others echoes Jack Triplett's (1971) perceptive suggestion more than three decades ago that the overall CPI bias could go either way because the bias has different signs for different products.

6.3 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 CPI bias, unmeasured quality change, or differences in the evolution over time of shelter rent and house prices.

The ratio of the 1999 to 1925 value of the CPI for rental shelter is 177.5/34.6 on a base of 1982–1984 = 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 6.1 in the following). 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 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. For wage earners, the 1988-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 as we would expect that the quality of owner-occupied houses has increased substantially more than that of rental apartments. For instance, there has

4. For aggregate sources, see table 6.1.

5. For 1925, the median asking price of existing homes in Washington, D.C. was $7,809, *Historical Statistics,* series N149. For 1999, the median price was $176,500, *Statistical Abstract* (2000, table 1202, 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, 726).

7. For 1988, Brown (1994, table 3.6A, 62) lists annual per-household expenditures on "rent" and "fuel and light" separately for each earner type. Table 7.8A (392–93) lists "tenant rent" and table 7.9 (398) lists "Renter fuel" and "Renter utilities." For 1918, see Brown (1994, table 3.6A, 62).

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]

6.4 Why Rental Shelter Prices Represent an Appealing Research Topic

The circumstantial evidence reviewed in the preceding, implying a substantial downward bias in the CPI, is only the first of several reasons to place priority on the research topic of this paper. Second, rental shelter carries by far the largest weight in the CPI, especially when one recognizes that owner-occupied housing 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 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 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

8. Rooms per apartment for 1918 come from Brown (1994, table 3.6A, 62). For 1988, we take the average of the mean values for 1987 and 1989 from the American Housing Survey data summarized in table 6.2.

9. In 2001, 80 percent of rental units had between three and five 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 eight+ rooms, whereas only 2 percent of rental units fell into this top category. See *Statistical Abstract* (2002, table 937, 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 1253, 753), and *Statistical Abstract* (2002, table 937, 599). The comment about dimensions of quality change is discussed further in the following.

10. The startling dichotomy between selling prices of homes in coastal "glamour" cities compared to the rest of the United States 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 1988–1997, with annual growth rates of rents of 3.3 percent for Milwaukee and 3.0 percent for Boston, see Goodman (2003, exhibit 1).

some other categories, especially consumer durable goods, before a final verdict on the implications of historical CPI bias could be rendered.

6.5 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, that is, 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 (CNV; 2003a,b) and shares with Crone, Nakamura, and Voith (2003b) the development of hedonic price indexes for rental shelter based on data from the American Housing Survey (AHS) for the period after 1975, ending in 1999 for Crone, Nakamura, and Voith and in 2003 for this study. However, our research strategy differs from that of Crone, Nakamura, and Voith (2003b), who are primarily interested in issues of functional form, whereas we are mainly interested in quality change. Because 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 this data richness to measure the rate of quality change and its determinants. This then allows us to apply these rates of quality change based on good data to earlier periods when we have much less detailed evidence.

For the period 1930–1975 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 Crone, Nakamura, and Voith (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 Gordon and Mandelkern (2001) for Evanston, IL covering the period 1925–1999, based on newspaper listings, and in some cases tracking rent changes for apartments having the same street address.

6.6 Comparing the CPI with Gross Rents over a Near Century

Table 6.1 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 (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 (CES).

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.[11] 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 column (6) presents the mean contract rent from the AHS data. Any differences between the CNV, Census, and AHS columns reflect the distinction between the median used by Crone, Nakamura, and Voith (2003) 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 6.1 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 more slowly than the comparison index, except for the Crone, Nakamura, and Voith (2003) version of the AHS index over the period 1985–1995. From 1914 to 1985, most of the alternative indexes of mean or median rent grow about 2 percent per year faster than the CPI, and this is true of the Grebler, Blank, and Winnick and Brown indexes that cover the pre-1935 period. Over 1930–1970, 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 Crone, Nakamura, and Voith–calculated median contract rent from the same Census of Housing data. The next line for 1960–1990 displays a difference between the CPI and Census of Housing mean rent at an annual rate of –2.03 percent, almost the same as the 1930–1970 difference. Finally, the next line for 1973–1988 displays the largest difference, that between the CPI and the Brown budget data of –3.10 percent per year.

The final three lines exhibit differences between the growth rates of the

11. The Census of Housing began in 1940, but Weston was able to infer similar data from the 1930 Census of Population.

Table 6.1 **Alternative measures of monthly rental expenditure, 1914–2001**

Year	CPI for rent (1982–84 = 100) (1)	GBW mean gross rent (2)	Weston mean gross rent (3)	CNV median contract rent (4)	Census mean contract rent (5)	AHS mean contract rent (6)	Brown CES budget study rent "salaried" (7)	Differences (8)	Differences (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					509.52			
1999	177.5					595.84			
2001	192.1			589.32		639.27			
2003	205.5					683.18			

(*continued*)

Table 6.1 (continued)

Year	CPI for rent (1982–84 = 100) (1)	GBW mean gross rent (2)	Weston mean gross rent (3)	CNV median contract rent (4)	Census mean contract rent (5)	AHS mean contract rent (6)	Brown CES budget study rent "salaried" (7)	Differences (8)	(9)
				Growth rates					
1914–1935	0.01	1.86					2.22	–1.85	–2.21
1935–1973	2.36						4.07		–1.71
1930–1970	1.00		3.12	3.13				–2.12	–2.13
1960–1990	4.25				6.28			–2.03	
1973–1988	5.93						9.03	–3.10	
1977–1985	6.82			9.40		8.50		–2.58	–1.68
1985–1995	3.45			3.40		4.53		0.05	–1.08
1995–2003	3.30					4.03			–0.73

Sources: Column (1): CPI for rent, 1982–1984 = 100, BLS web site, series CUUR0000SEHA, "U.S. City Average, Rent of Primary Residence, 1982–1984 = 100."

Column (2): Grebler, Blank, and Winnick (1956). Total nominal expenditures on aggregate rental expenditures from table I-1 on page 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," and so on. Number of nonfarm households from table 23 on page 82. Mean gross rent is aggregate rental expenditures divided by total nonfarm households.

Column (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.

Column (4): Calculated from Crone, Nakamura, and Voith (2003b, table 11), starting with our 1977 value in column (5) from the AHS data, and working forward and backward by calculating the Crone, Nakamura, and Voith annualized growth rates into changes in levels using the exponential function. This conversion introduces an unknown degree of error, because the growth rates calculated by Crone, Nakamura, and Voith in their appendix 2 are not accurate calculations of compound growth rates using natural logs.

Column (5): Integrated Public Use Microdata series, University of Minnesota, http://www.ipums.org.

Column (6): Mean of all observations in AHS regression data. For issues involved in sources and manipulation of AHS regression data, see data appendix.

Column (7): Brown (1994), for the five years shown, the source tables and page numbers are 1918, table 3.6A, page 62; 1935, table 4.8, page 127; 1950, table 5.10, pages 212–13; 1973, table 6.8A, pages 294–95; 1988, table 7.8A, pages 392–93.

CPI and the AHS data, both as calculated by Crone, Nakamura, and Voith (2003) 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 1977–1985 to –1.08 percent per year in 1985–1995 to –0.73 percent per year in 1995–2003, whereas in the Crone, Nakamura, and Voith (2003) calculation (column [8]) the difference starts higher and ends lower. These "differences" do not, of course, provide any evidence of bias in the CPI as in principle the differences could be explained by quality change. Subsequently, we shall estimate hedonic price indexes for the 1975–2003 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 6.1 are intriguing. The differences were close to 2 percent per year over most of the period after 1930 and before 1989. The difference was minor during 1914–1930 in the first line and was relatively small for 1995–2003 in the last line. Obviously, a conclusion that quality change proceeded at a rate of 2 percent per year would explain the differences displayed in the bottom of table 6.1 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 2 percent per year, for example, 1.0 or 0.5 percent per year, would support the hypothesis that the CPI is downward biased by the difference shown at the bottom of table 6.1 and the calculated rate of quality improvement.

6.7 Conceptual Issues in the Development of Rental Price Indexes

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 rental equivalence for owner-occupied housing, and 2.7 percent for lodging away from home (Greenlees 2003, 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, for example, a reduction in interest rates that (as in 2001–2003) 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, 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 Bajari, Benkard, and Krainer 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.[12] Anecdotal evidence suggests that low interest rates in 2001–2003 made the purchase of condominium units so attractive that an oversupply of apartments and softness of rents developed in many cities.

Díaz and Luengo-Prado (2003) provide a convincing explanation of a fundamental puzzle, which is why, in the perspective of subsidies and ad-

12. 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.

vantages 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.[13] 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.

An 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 or property taxes) 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, implying low nominal rent inflation, the advantages of home ownership would diminish accordingly.

6.8 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

13. The proportion of owner-occupiers has increased substantially over time. Brown (1994, table 3.6A, 62) indicates that in 1918 only 19 percent of "laborer" households were homeowners, compared to 24 percent of "wage earners" and 36 percent of "salaried" workers.

units and the methodology returned to the same as during the 1983–1986 period, namely to reweight the rent sample to represent owner-occupied units.[14]

The ex-ante assumption of downward bias in the CPI is based on more than the circumstantial evidence reviewed in the preceding. 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 experiences 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 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 Crone, Nakamura, and Voith (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 often has no knowledge of the rent paid by the previous tenant. Crone, Nakamura, and Voith (2003a) estimate that over the period 1942–1977 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.[15] 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 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).

14. Facts in this paragraph come from Placek and Baskin (1996).

15. This history of CPI improvements is taken from Crone, Nakamura, and Voith (2003a, 11–12).

We have seen in table 6.1 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 2 percent per year. Crone, Nakamura, and Voith (2003a) present adjustments based on a theoretical model of nonresponse bias; their average bias correction for 1930–1985 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 subperiods that overlap with the Crone, Nakamura, and Voith (2003) results.

6.9 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, for example, Wallace (1996), Meese and 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 versus 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, 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.

Our hedonic study of rents from the AHS shares with Crone, Nakamura, and Voith (2003b) the absence of data on location, except for four regions of the country and urban versus 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 as rental units typically have little or no attached land and are more homogeneous than owner-occupied units in many dimensions.[16]

6.9.1 Mean Values

The AHS data examined in our hedonic regression study extends from 1975 to 2003 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 consist of three separate panel data sets covering, respectively, 1975–1983, 1985–1995, and 1997–2003. The number of variables included jumps in the second data set. As Crone, Nakamura, and Voith (2003b, 8) also found, estimated regression coefficients for the time period 1983–1985 are problematic because of the lack of homogeneity of the panels between 1983 and 1985, and we have further found that the 1985–1995 panel cannot be merged with the 1997–2003 (see further discussion in the data appendix).

Table 6.2 displays for 1975, 1985, 1993, and 2003, 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 6.1. Particularly interesting on the second line is the size of the rental unit measured in square feet (available only starting in 1985), and this changes remarkably little in contrast to the much more rapid growth in the size of new single-family houses, which over 1970–2001 experienced an increase in median square feet of 52 percent and in mean square feet of 55 percent.[17] Other measures of size also show little increase between 1975 and 2003. There is a large jump in average age that presumably reflects changes in the panel of units.

The quality characteristics in table 6.2 are divided into five sections, at the top those representing quantitative attributes like square feet and then below an array of dummy variables representing location, positive quality attributes, negative physical and environmental characteristics, and, fi-

16. 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 the variation in a hedonic price index over time.

17. See *Statistical Abstract* (1987, table 1273, 706; 2002, table 922, 591). The median went from 1,385 square feet in 1970 to 2,103 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, and Winnick 1956, 119).

Table 6.2 **Mean values, AHS data**

Variable	1975	1985	1993	2003
Rent	135.20	314.50	453.10	683.18
Unit square feet	n.a.	1,058.68	1,075.52	1,040.98
Bedrooms	1.84	1.88	1.92	1.94
Other rooms	2.24	2.39	2.43	2.38
Approximate age	25.22	30.81	37.10	42.38
Northeast region (%)	25.68	24.04	23.37	17.29
Midwest region (%)	23.25	23.15	21.51	21.29
South region (%)	30.50	30.09	31.17	30.94
West region (%)	20.57	22.73	23.95	30.48
Urban area (%)	57.76	89.66	87.22	87.00
Has multiple bathrooms	6.57	15.51	15.20	20.23
Has central air conditioning	14.99	26.93	35.68	45.52
Interaction: Central air & NE	5.05	8.74	1.16	3.34
Interaction: Central air & MW	13.07	23.48	5.27	9.37
Interaction: Central air & S	28.33	50.04	21.79	23.22
Interaction: Central air & W	9.77	19.06	7.47	9.59
Has dishwasher	n.a.	28.24	32.80	43.29
Has fireplace	n.a.	11.20	20.06	12.30
Has porch	n.a.	56.92	74.85	71.75
Has elevator	7.89	9.80	1.99	9.02
Garage included in rent	n.a.	27.98	48.78	35.15
Lacks piped hot or cold water	n.a.	0.68	0.65	0.27
Incomplete plumbing fixtures	4.67	1.20	2.08	2.00
No sewer connection	16.43	9.24	20.51	6.28
Visible wiring	n.a.	3.35	0.77	0.79
Signs of rodents	11.87	7.52	20.63	12.88
Holes in floors	3.67	2.92	2.56	1.43
Cracked walls	n.a.	10.76	10.89	7.21
Noise problem	n.a.	11.22	3.45	3.29
Litter problem	n.a.	4.31	1.82	2.08
Neighborhood bothersome	n.a.	40.26	15.92	14.53
Public housing	6.83	7.36	1.61	4.37
Rent is federally subsidized	1.68	4.37		
Rent is locally subsidized	n.a.	1.46		
Rent is federally subsidized or locally subsidized (1997 and 2003)			2.80	5.44

nally, special aspects of rental finance, for example, whether the unit is in public housing 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 2003. The presence of air conditioning increases from 15 percent of the units in 1975 to 46 percent in 2003, while multiple bathrooms increases from 7 to 20 percent. Units having no sewer connection decreased from 16 percent in 1975 to 6 percent in

2003. There is a modest improvement in the variables in the bottom of the table measuring negative externalities.

6.9.2 Regression Estimates

Estimated coefficients for the full set of available variables are shown separately in table 6.3 for three periods, the first panel covering 1975–1983, the second panel covering 1985–1995, and the third for 1997–2003. Explanatory variables are listed in the same order as in table 6.2. All regressions are estimated in double-log form and thus differ from the Box-Cox flexible functional form estimated by Crone, Nakamura, and Voith (2003b) and the semilog form used by Randolph (1988).[18] All coefficients displayed in table 6.3 are significant at the 1 percent level or better (except for scattered negative attributes in 1997–2003), which is perhaps not surprising in light of the large sample sizes of between 30,000 and 52,000 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 (although the rent-lowering movement to the South is partly or entirely cancelled by the rent-raising movement to the West). A few of the coefficients are surprising—the coefficient on central air conditioning seems small and declines rapidly to a negligible 5 percent, whereas the coefficients on dishwasher and fireplace seem surprisingly large and may be correlated with other unmeasured attributes, for instance high-grade kitchen cabinets and countertops in the case of "dishwasher" and a higher general level of amenities and trim in the case of "fireplace."

The time dummy coefficients at the bottom of table 6.3 provide an alternative measure of inflation for every two years over the period 1975–2003, except for 1983–1985 and 1995–1997. 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 Crone, Nakamura, and Voith (2003b).

6.10 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

18. Crone, Nakamura, and Voith (2003b, table 5) show that the average rate of increase of their hedonic price index is insensitive to alternative functional forms.

Table 6.3 Parameter estimates, AHS data

Variable	1975–1983	1985–1995	1997–2003
Intercept	4.91**	5.00**	5.16**
ln(Unit square feet)		0.04**	0.07**
ln(Bedrooms)	0.15**	0.09**	0.07**
ln(Other rooms)	0.11**	0.10**	0.10**
ln(Approximate age)	–0.18**	–0.07**	–0.04**
Northeast region	0.26**	0.37**	0.30**
Midwest region	—	—	—
South region	–0.31**	–0.21**	–0.23**
West region	0.15**	0.32**	0.29**
Urban area	0.16**	0.28**	0.26**
Has multiple bathrooms	0.31**	0.17**	0.17**
Has central air conditioning	0.17**	0.11**	0.05**
Interaction: Central air & NE	0.15**	–0.06**	–0.02
Interaction: Central air & MW	—	—	—
Interaction: Central air & S	0.28**	0.18**	0.18**
Interaction: Central air & W	–0.18**	–0.22**	–0.16**
Has dishwasher		0.16**	0.21**
Has fireplace		0.10**	0.12**
Has porch		–0.04**	–0.03**
Has elevator	0.06**	0.21**	0.19**
Garage included in rent		0.09**	0.09**
Lacks piped hot or cold water		–0.89**	–0.39**
Incomplete plumbing fixtures	–0.79**	–0.11**	–0.01
No sewer connection	–0.08**	–0.10**	–0.11**
Visible wiring		–0.06**	0.01
Signs of rodents	–0.08**	–0.04**	–0.02
Holes in floors	–0.10**	–0.05**	–0.02
Cracked walls		–0.02**	–0.05**
Noise problem		0.02**	0.01
Litter problem		–0.03**	–0.02
Neighborhood bothersome		0.02**	0.02*
Public housing	–0.60**	–0.65**	–0.58**
Rent is federally subsidized	–0.33**	–0.28**	
Rent is locally subsidized		–0.13**	
Rent is federally or locally subsidized (for 1997–2003 only)			–0.20**
1977 time dummy	0.22**		
1979 time dummy	0.30**		
1981 time dummy	0.49**		
1983 time dummy	0.63**		
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**	
1999 time dummy			0.13**
2001 time dummy			0.21**
2003 time dummy			0.26**
Adjusted R^2	0.51	0.41	0.27
Degrees of Freedom	30,811	52,169	33,015
Standard Error of Estimate	0.52	0.51	0.61
Sum of Squared Residuals	8,268	13,424	12,233

Note: In this and subsequent tables, ** indicates statistical significance at the 1 percent level and * indicates statistical significance at the 5 percent level.

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, that is, locational variables and government-related variables (public housing and subsidized housing).

To implement this distinction between quality and nonquality explanatory variables, we remove variables in several steps, as shown in table 6.4. Starting from the full regression in column (1), the first step is to remove all

Table 6.4 Effect of stripping sets of variables, AHS data, 1975–2003

Variable	Full specification (1)	Weston analysis specification (2)	Weston + housing subsidy variables (3)	Removed quality variables (4)	Year only (5)
1975–1983 sample					
1977 time dummy	0.22**	0.18**	0.21**	0.19**	0.17**
1979 time dummy	0.30**	0.35**	0.36**	0.36**	0.35**
1981 time dummy	0.49**	0.56**	0.57**	0.56**	0.58**
1983 time dummy	0.63**	0.69**	0.71**	0.70**	0.68**
SEE	0.52	0.57	0.54	0.64	0.70
SSR	8,268	9,965	8,952	13,273	15,384
1985–1995 sample					
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**
SEE	0.51	0.58	0.55	0.58	0.65
SSR	13,424	26,898	23,899	27,601	34,317
1997–2003 sample					
1999 time dummy	0.13**	0.17**	0.18**	0.13**	0.17**
2001 time dummy	0.21**	0.24**	0.25**	0.21**	0.24**
2003 time dummy	0.26**	0.30**	0.32**	0.27**	0.31**
SEE	0.61	0.67	0.64	0.66	0.71
SSR	12,233	14,219	13,449	14,946	17,102
Annual growth rates					
1975–1983	7.83	8.63	8.88	8.81	8.53
1985–1995	4.48	5.36	5.42	4.86	4.96
1997–2003	4.33	5.00	5.33	4.50	5.17
Difference from column (1)					
1975–1983		0.80	1.05	0.98	0.70
1985–1995		0.88	0.94	0.37	0.48
1997–2003		0.67	1.00	0.17	0.83

quality variables other than those available in Weston's analysis of the 1930–1970 period (discussed in the following). Thus column (2) retains the number of rooms, age, and incompleteness of plumbing fixtures, as well as regional location. The housing subsidy variables are added back in columns (3) and (4), while column (4) removes all remaining quality variables. Column (5) removes all explanatory variables other than the time dummies.

We will discuss the differences in the annual rates of price change over each of the three intervals in succession, starting with 1975–1983, and we refer to the annual growth rates of the time coefficients summarized in the bottom three lines of table 6.4. Comparing columns (1) and (2) provides evidence on the effect of quality variables not available to Weston, especially multiple bathrooms, air conditioning, and presence of an elevator. For 1975–1983, these quality variables explain 0.80 percent per year of price change, and a comparison of columns (1) and (4) indicates that removing all quality variables (while leaving in the regional and subsidy dummies) explains 0.98 percent per year of price change. The regional and subsidy effects, dropped in going from column (4) to (5), contribute –0.28 percent per year, indicating that apartment rents were pulled down by a movement to the South and an increased share of subsidized rental housing.[19] Because the CPI controls for location and such attributes as public financing, we want to include those variables in the regressions compared with the CPI, as in columns (1), (3), and (4).

The next section of table 6.4 carries out the same exercise for the subsequent decade 1985–1995 when our set of explanatory variables is considerably richer. The result in going from column (1) to (2) is slightly larger; 0.88 percent per year of price change is explained 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 6.2. For the 1985–1995 decade, a comparison of the final two columns indicates that removing the regional and subsidy variables adds back in 0.11 percent per year of price change.

The final section of table 6.4 presents results for 1995–2003. The annual rate of price change explained by quality change in going from column (1) to (2) of table 6.6 is 0.67 percent per year, but again going from column (2) to (4) reveals a quality deterioration of 0.50 percent per year that may be explained by increasing age. Because the sharp jump in age in going from 1975 to 2003 (see table 6.2) is implausible, it may reflect an inconsistency in

19. 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 number of years in each interval.

Table 6.5 **Effects of stripping sets of variables, census microdata, 1960–1990**

Variable	Census hedonic (1)	Quality variables removed (2)	Year only (3)
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
Degrees of Freedom	708,246	7E+05	708,253
Standard Error of Estimate	0.49	0.53	0.57
Sum of Squared Residuals	170,047	2E+05	224,586

Source: Census microdata extract courtesy of the IPUMS project (http://www.ipums.umn.edu/).

the AHS sample for which we have not yet found an explanation.[20] Removal of the regional and subsidy dummy variables raises price change by 0.66 percent per year. Overall, the regressions reduce the change in the hedonic index by 0.83 percent below the raw price change in the sample, of which just 0.17 points is attributable to quality change and 0.66 points to the regional or subsidy effects.[21]

6.11 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 6.5 we present in column (1) the full hedonic regression result, in column (2) the effect of removing the

20. One source of inconsistency in the AHS sample is that the 1975–1983 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.

21. To check on the stability of the results during 1997–2003, we ran separate adjacent-year regressions for 1997–1999, 1999–2001, and 2001–2003. Not surprisingly in light of the large samples, the quality and time coefficients in the adjacent-year regressions were almost identical to the six-year regression results shown in table 6.6.

quality variables, and in column (3) 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 1960–1970, the price increase in column (2) is 10 percent faster than in column (1), indicating a quality effect of 1.0 percent per annum. However, the quality effect declines to 0.60 percent per annum for 1960–1980 and to 0.37 percent per annum for 1960–1990. Decade-by-decade, the implied quality change was at a rate of 1.0 percent per annum in 1960–1970, 0.2 percent in 1970–1980, and –0.1 percent in 1980–1990.

The results in table 6.4 and 6.5 are converted to annual growth rates and summarized in table 6.6. The four lines represent the period of the Census data (1960–1990) and the three subperiods of the AHS data (1975–1985, 1985–1995, and 1995–2003). A comparison of columns (2) and (5) in the first line indicates an annual growth rate of quality over 1960–1990 of 0.37 percent per year and a difference between the CPI and Census hedonic (column [8] minus column [1]) of –1.67 percent per annum.

The next three lines of table 6.6 summarize the results using the AHS data. The years of data gaps, 1983–1985 and 1995–1997, are bridged by assuming that each AHS variant index grew at the same rate as the CPI during those two pairs of years. Thus, for the 1975–1985 and 1995–2003 intervals shown in table 6.6, the results shown in columns (2) through (6) are biased toward zero by design. Column (1) displays the baseline regression results of Crone, Nakamura, and Voith (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 1975–1985 but is very close in 1985–1995. As discussed previously, 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 0.60, 0.88, and 0.37 percent, respectively, an amazingly consistent record. Removing all quality variables in column (5) implies, in comparison with the full hedonic results in column (2), respective rates of "total" quality change of 0.70, 0.38, and 0.09 percent per year. The implied CPI bias (comparing column [8] with column [2]) is –1.05, –1.03, and –0.78 percent per annum.

Figure 6.1 summarizes the hedonic regression results, displaying the Census- and AHS-based hedonic price indexes and the CPI for the period 1960–2003. The Census hedonic indexes and the CPI are expressed on a basis of 1970 = 100, and the AHS index is linked to the Census index in 1975, which amounts to expressing the AHS index on a 1970 base year with the Census average growth rate for 1970–1980 used to proxy the missing AHS observations for 1970–1975. During the overlapping period of 1975–1990, the Census and AHS indexes are surprisingly close in light of the much longer list of explanatory variables in the AHS data set, indicating that the location and subsidy variables essentially offset the effect of the quality variables.

Table 6.6 Annualized growth rates, by index

Time period	CNV 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	7.61	8.21	8.41	8.31	8.11	8.44	6.56
1985–1995	4.66	4.48	5.36	5.42	4.86	4.96	4.53	3.45
1995–2003	n.a.	4.08	4.58	4.83	4.20	4.70	5.38	3.30

Sources: Column (1): Crone, Nakamura, and Voith (2003b, table 5). Columns (2) through (6) are computed by setting the rate of change of the hedonic index equal to that of the CPI for 1983–1985 and 1995–1997, reflecting the inability to mesh data for 1983 with 1985, or data for 1995 with 1997. Column (7): AHS, IPUMS Census Microdata, see table 6.1. Column (8): BLS.

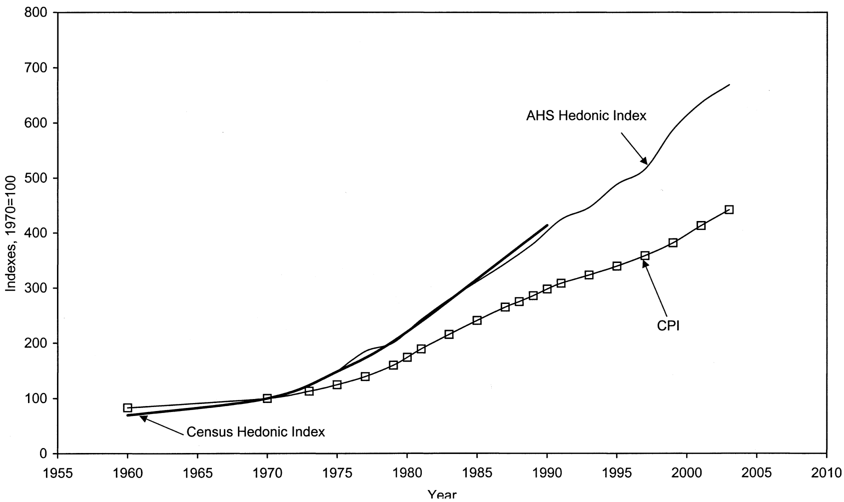

Fig. 6.1 CPI and hedonic price indexes from Census and AHS data, 1960–2003

6.12 Additional Quantitative Evidence on Quality Change, 1918–1970

6.12.1 The Weston Data and Analysis

Our main source of changes in rent for the period 1930–1970 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 analysis of variance (ANOVA)–based methodology. He then conducted an analysis of quality change, measuring the implied quality change associated with each vari-

Table 6.7 **Mean gross rent and two price indexes from Weston's data, 1930–1970**

Year	Mean gross rent	Weston price index	Törnqvist index from Weston data	Implied quality index from: Weston	Implied quality index from: Törnqvist
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					
1930–1940	–0.73	–0.26	–0.17	–0.47	–0.56
1940–1950	4.00	4.28	4.00	–0.28	0.00
1950–1960	4.86	3.98	4.49	0.88	0.37
1960–1970	4.35	2.73	2.85	1.63	1.50
1930–1970	3.12	2.68	2.79	0.44	0.33

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

able and its interaction terms. Weston produced price indexes for both house prices and rents.

Table 6.7 in the first column copies from table 6.1 the mean gross rent data that Weston obtained from the Census. As calculated in table 6.1, this series increases 2.1 percent per year more rapidly than the CPI for rent over the period 1930–1970. 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 Törnqvist 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 1950–1960. Only in the final decade, 1960–1970, did quality improve rapidly.

The bottom part of table 6.7 calculates annual growth rates for each decade and for the four decades taken together. Over the full period 1930–1970, the Weston price index increases at 0.44 percent per year less than

Table 6.8 **Weston quality attributes**

	1930	1940	1950	1960	1970
Age					
0–10	30.5	10.8	14.5	16.6	19.6
>10	69.5	89.2	85.5	83.4	80.4
Rooms					
1–2	11.7	16.8	17.7	14.8	5.7
3–4	32.7	41.3	52.1	52.9	32.2
5–6	37.4	33.5	26.3	27.9	44.5
>6	18.1	8.4	3.9	4.4	17.6
Mean[a]	4.65	4.13	3.81	3.91	4.89
Condition					
Not dilapidated	82.6	84.6	89.6	93.9	97.0
Dilapidated	17.4	15.4	10.4	6.1	3.0
Plumbing					
With all	57.5	63.9	68.3	81.9	93.4
Lacking	42.5	36.1	31.7	18.1	6.6
Weighted mean of rent ratio[b]	1.96	2.07	1.58	1.79	1.76

[a]Calculated on midpoints of each bin; 7 was used for the last bin.
[b]Mean ratio of rent for a unit with proper plumbing to one without, weighted by quantity.

mean gross rent, and the Törnqvist 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 1930–1960 and then accelerated so much from 1960 to 1970. Several answers are suggested in table 6.8, 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 ten 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.[22] In the following, we attempt to make a rough correction for the value of improvements over time in heating, plumbing, and electrification.

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

Table 6.9 Mean values, census microdata

Variable	1960	1970	1980	1990
Rent	62.31	98.95	216.04	410.03
Bedrooms	1.7	1.8	1.8	1.9
Other rooms	2.2	2.2	2.3	2.2
Approximate age	23.9	21.6	23.7	26.3
Northeast region (%)	31.5	29.4	26.4	22.4
Midwest region (%)	24.6	23.5	22.3	20.6
South region (%)	27.1	27.1	28.2	31.2
West region (%)	17.2	19.9	23.1	25.4
Incomplete plumbing fixtures	17.8	6.1	0.9	0.7

Because Weston's quality correction for 1960–1970 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 6.5. As shown in table 6.7, the unadjusted annual growth rate of rent for 1960–1970 is 4.35 percent for Weston and in table 6.9 is 4.63 percent for the Census microdata. The Weston price index based on the Törnqvist method increases at 2.73 percent per year compared to 3.6 percent for the Census hedonic price index of table 6.5. 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 6.8 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 –0.71 in the Census microdata regression in table 6.5.

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 6.8 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. We note from table 6.2 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 1960–1970 decade and prefer the conclusion of the hedonic price index developed from the Census microdata.

6.12.2 Brown's Evidence on Quality Change

In table 6.1 we have already examined Brown's rental prices from five budget studies based on CES data spanning the period 1918–1988. We found that over the 1918–1973 period, Brown's rental price per unit increased at about 1.9 percent per year faster than the CPI. 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.

Of the quality changes that Brown quantifies or discusses over the five years of her study (as shown above in table 6.1), 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 6.7 and 6.8. The best that we can do to extract data from the Brown study is presented in table 6.10. 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 6.10. 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 as 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.[23] 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.[24]

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 because rental units were predominately located in large cities, it is likely

23. Brown (1994, 40) indicates that median household income in the CES sample was $1,400 in 1918. The mean income for her three classes are $1,037 for laborers, $1,344 for wage earners, and $2,272 for salaried workers.

24. See *Statistical Abstract* (2002, table 937, 599).

that the data on the third line of table 6.10 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 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 as 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 6.8 for 1950 was 32 percent; the Weston number of 18 percent for 1960 agrees with the Census number of 18 percent in table 6.9.

Table 6.10 **Data on characteristics of rental units and all dwelling units, 1918–1973**

	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	212–213			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.

Some additional insight into the quality of housing units (both tenant-occupied and owner-occupied) in 1935 can be obtained from the description of a "typical American home" from the U.S. BLS (1935) as quoted by Brown (1994, 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, 215)

6.12.3 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, and Winnick (1956, 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 multifamily building over the years between the construction date and the data source in 1950. They argue that because conversions to increase the density of multifamily 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 previously. 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" (Grebler, Blank, and Winnick 1956, 121).

6.13 Quantifying Quality Change

To summarize our findings on quality change to this point, we found that quality attributes available in the 1975–2003 AHS data but not available in the Weston or Census of Housing data contributed an average of 0.67 percent per year to explaining price change (table 6.6, comparison of columns

[2] and [3]). 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 6.9, line 3) as in the AHS data (table 6.2, 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 1960–1970, but at a negligible rate of 0.05 percent per year during 1970–1990.

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 1975–1985 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 1918–1930 interval.[25]

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 0.05 to 0.17 in table 6.3, averaging out at 0.11. Over the period 1975 to 2003, the percentage of units with central air conditioning in the AHS sample increased from 15 to 46 percent, and this can be translated into an annual rate of improvement of quality of 0.11 percent per year.[26] It could be argued that the value of central heat was less than the value of air conditioning as housing units were already heated, albeit inconveniently,

25. 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.

26. Following the procedure in the previous footnote, a complete conversion from 0 percent to 100 percent central air conditioning would raise the log value of the average apartment by 0.11. The observed increase of 29 percentage points raised the log value by 0.11 times .29, or 0.031, and this occurred over twenty-eight years for an annual rate of improvement of 0.031/28, or 0.11 percent per year.

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, more than double the average 1975–2003 coefficient of 0.11 on central air conditioning. 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.

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 1918–1930 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, 225).

6.14 Merging the Prehedonic and Hedonic Results into a Century-Long Perspective

Thus far the discussion in this paper has combined two quite different perspectives on quality change, those based on hedonic regressions from Census data for 1960–1990 and AHS data for 1975–2003, with more impressionistic evidence on the pre-1960 period. Table 6.11 provides a systematic summary of all the results in the paper, with the columns representing the seven subperiods suggested by breaks in the data sources. The first three lines exhibit a summary of the information already presented in

Table 6.11 Summary of results on quality change, other determinants of rent, and implied CPI bias, 1914–2003 (annual growth rates in percent)

	1914–1935	1935–1960	1960–1970	1970–1975	1975–1985	1985–1995	1995–2003
1. CPI	0.01	2.37	1.84	4.42	6.56	3.45	3.30
2. Actual mean or median rent	2.04	4.28	4.63	6.24	8.44	4.53	4.03
3. Difference between CPI and actual rent	–2.03	–1.89	–2.79	–1.82	–1.88	–1.08	–0.73
4. Value of quality change							
a. Plumbing	0.39						
b. Central heating	0.39	0.39	0.39				
c. Electrification	0.39	0.39					
d. Weston quality index		0.09					
e. Census hedonic quality index			1.00	0.20			
f. AHS hedonic quality index					0.88	0.40	0.10
5. Total change in value of quality	1.17	0.87	1.39	0.20	0.88	0.40	0.10
6. Other rent determinants (location, subsidy)			0.10	0.00	–0.25	0.10	0.40
7. Fully adjusted rent (comparable to CPI)	0.87	3.41	3.14	6.04	7.81	4.03	3.63
8. Implied CPI bias	–0.86	–1.04	–1.30	–1.62	–1.235	–0.58	–0.33

Source: Row (1): CPI from table 6.1, column (1). Row (2): 1914–1935, the average of the growth rate of the Grebler, Blank, and Winnick (1957) index in table 6.1, column (2) for 1914–1935 (1.86) with the Brown index in table 6.1, column (7) for 1918–1935 (2.22). 1935–1960, the average of the growth rate of the CPI for 1935–1940 and for 1940–1960 the average of the growth rates of the Weston mean gross rent data from table 6.1, column (3) with the Crone, Nakamura, and Voith (2003) data in table 6.1, column (4). 1960–1970 from the Census mean contract rent, table 6.1, column (5). 1970–1975 is the growth rate from the 1970 Census figure in table 6.1, column (5) to the AHS figure in table 6.1, column (6). Growth rates after 1975 all come from the AHS data in table 6.1, column (6). Row (3): Row (1) minus row (2). Rows (4a–c): See text discussion. Note that the plumbing adjustment is incorporated in the Weston quality index after 1930, which for this discussion we take to mean 1935. Row (4d): Average growth rate of the two quality indexes in table 6.7 between 1935 and 1960, with 1935 interpolated linearly between 1930 and 1940. Row (4e): Time dummy coefficient for 1970 versus 1960 from table 6.5, column (2) minus column (1). 1970–1975 is taken as the annual growth rate of 1980 versus 1970 from table 6.5, column (2) minus column (1). Row (4f): From table 6.4, the annualized growth rate of the time dummy coefficients in column (4) minus column (1). Row (5): The sum of all rows in section 4. Row (6): For 1960–1970 and 1970–1980, the annualized growth rate of the difference in the time dummy coefficients in table 6.5, column (3) minus column (2). For 1975–2003, the annualized growth rate of the difference in the time coefficients in table 6.4, column (5) minus column (4). Row (7): Row (2) minus the sum of rows (5) and (6). Row (8): Row (1) minus row (7).

table 6.1 about the annual growth rate over these seven intervals in the CPI and mean or median nominal rent unadjusted for changes in quality or location, and the difference between the growth rate in the CPI and average rent, which is negative in all seven periods, with an average difference of about –2 percent over the interval 1914–1985, with a smaller difference after 1985.

Line 4 of table 6.11 has six sections that extract from all of our previous results the implied rate of quality change in rental units. For 1914–1935 we have conjectured estimates of the contribution of improved plumbing, central heating, and electrification, based in part on coefficients from hedonic regressions for the post-1960 period. For 1935–1960 we drop the plumbing estimate as plumbing is one of the quality characteristics explicitly controlled in Weston's approach. He also controls for location, age, and condition, characteristics that may have either a positive or negative influence on rent and which are not taken into account in the pre-1935 period.

Our hedonic regressions provide most of the evidence on quality change after 1960, except that we add an explicit allowance for heating, which (along with air conditioning) is one of the variables missing from the Census data used to cover the 1960–1975 period. After 1975 the quality estimates are entirely based on the "stripping exercise" carried out for the AHS data in table 6.4, in which we removed quality variables from the regressions to isolate the separate effects of the Weston quality variables, other quality variables, and the location and subsidy variables.

In table 6.11, line 5 sums the various sources of quality change, line 6 adds in the effects of the location and subsidy variables in the hedonic regressions, and the final comparison of lines 1 and 7 provides the bottom-line estimates of the CPI bias, which is uniformly negative in each of the seven periods. The average bias for 1914–2003 is –0.97 percent per year. For the period before major improvements in CPI methodology, 1914–1985, the average bias is –1.09 percent per year. For the period emphasized by Crone, Nakamura, and Voith as involving the tenant nonresponse problem, represented here by 1935–1985, the average bias is –1.19 percent per year.

Over the entire 1914–2003 period, the average annual rates of change are mean rent 4.37, CPI 2.54, and this CPI-rent difference of –1.83 is divided between a 0.86 contribution of quality (including a small contribution of location/subsidy) and a remaining –0.97 estimated CPI bias. Thus our initial conjecture that the 2 percent difference between the growth of mean rent and the CPI might be explained roughly half-and-half by quality, and CPI bias appears to be roughly validated by the results.

6.15 A Study of Apartment Rents in a Specific Locality, 1925–1999

A final piece of long-term historical evidence on tenant rents comes from a project designed to collect detailed rent data at the local level in order to assess historical changes in the CPI for rent. This local data set has the advantage in that it allows us to control for many types of quality change as discussed previously, 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.[27] 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 factors allowed us to collect data on tenant rent and prices for a variety of living units over the past seventy-five years.

The first phase of our research involved collecting apartment prices over the interval 1925–1999 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, 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.

27. This is a summary of Gordon and Mandelkern (2001). See also Mandelkern (2001).

Table 6.12 **Evanston apartment rent indexes and CPI, 1925 = 100**

				No. of observations	
Year	CPI for rent	Specific address index	Median index	Address index	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	1,087.1	1,257.6	10	26
Annual growth rates					
1925–1950	–0.60	1.19	1.45		
1950–1975	2.67	3.66	3.61		
1975–1999	4.60	4.90	5.27		
1925–1975	1.04	2.42	2.53		
1925–1999	2.19	3.22	3.42		

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 in the following). 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 6.12.

It is important to note that while our Evanston indexes are matched-model indexes like the CPI, we have the important advantage that we have no problem with tenant nonresponse bias as emphasized by Crone, Nakamura, and Voith (2003). All of the price information that we have collected is based on newspaper ads and thus is obtained directly from landlords, not tenants.

To supplement the first index, we grouped apartments into categories based on the number of rooms for three-, four-, five-, and six-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 "one bedroom" was better averaged with the "three-room" or "four-room" categories. However, many ads included wording such as "one-bedroom, four-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 basis that X bedrooms equals ($X + 3$) rooms.

After compiling the mean data for three-, four-, five-, and six-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 three-room and six-room apartments. To make up for this, we compiled an index including only four- and five-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 three-, four-, five-, and six-room apartments. Because the median, mean, and the four–five-room indexes were very close, table 6.12 displays only the Specific Address index and the Median index for three-, four-, five-, and six-room apartments.

Differences between the CPI and the two new apartment rent indexes are summarized at the bottom of table 6.12, which displays average annual growth rates over the intervals 1925–1950, 1950–1975, and 1975–1999. 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 1925–1950, 0.98 percent per year in 1950–1975, and a much smaller 0.29 in 1975–1999. 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 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 seventy 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). Because 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 1925–1975 period, the difference between the CPI and our two indexes are –1.38 and –1.49 percent, respectively, and this compares with the average CPI bias in table 6.11 for 1914–1975 of –1.07 percent. The smaller bias in the national results in table 6.11 could indicate that rents have risen faster in Evanston than in the nation as a whole or that our Evanston indexes may miss some elements of quality change.

6.16 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 2003. 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 (2003a) that traces the downward bias primarily to nonresponse by tenants who moved just as rents were raised. Crone, Nakamura, and Voith (2003a) 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.[28] Our initial examination of data finds that the 2 percent difference extends to other time periods and data sources, as summarized in the bottom section of table 6.1. The difference was much less after 1987, reflecting presumably an improvement in CPI methodology.

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 1975–2003. 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 tradi-

28. See table 6.1, where we take for 1940 the average of the values in columns (3) and (4).

tional 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 partly spurious. The nontraditional quality characteristics consistently contribute about 0.7 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 1960–1990. 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 1960–1970 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 1930–1970. 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 1960–1970. Aspects of the Census data look more plausible to us for the 1960–1970 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 rely on Weston's cross-classification of rents and quality characteristics to develop a basic measure of quality change for 1930–1960. Second, we stitch together data on the diffusion of important quality attributes of rental units, including plumbing, heating, and electrification, over the period 1918–1973. Applying guesstimates about the value of these attributes based in part on the post-1960 hedonic regression coefficients, we conclude that quality change in the 1918–1973 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. As summarized in table 6.11, we estimate that quality improved at an annual rate of about 1.2 percent during 1914–1935 and 0.9 percent during 1935–1960.

Our final piece of evidence is based on a study of rents in a single local community, Evanston, IL, covering the period 1925–1999. 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 1925–1975, about –0.4 percent more than the CPI bias estimates based on the nationwide data.

Our overall conclusions are surprisingly consistent that the CPI bias was roughly –1.0 percent prior to the methodological improvements in the CPI that date from the mid-1980s.[29] Our reliance on a wide variety of methodologies and of evidence on types of quality change and their importance, while leaving the outcome still uncertain, at least in our view substantially narrows the range of possibilities regarding the history of CPI bias for rental shelter over the twentieth century.

Data Appendix

American Housing Survey (AHS)

This paper uses fifteen cross-sections of American Housing Survey[30] microdata for 1975–2003, courtesy of the Inter-University Consortium for Political and Social Research, and the U.S. Department of Housing and Urban Development. 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 years. 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 data sets provide a robust set of characteristic and quality variables that are well suited for the estimation of hedonic price equations.

The original 1973–1983 AHS panel was based on the 1970 Census of Housing. In 1985, the panel and survey form were redesigned to improve data quality and 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 that cannot be recorded in basic characteristic data and thus cannot be priced by a traditional hedonic approach.

29. Hence we reject the Crone, Nakamura, and Voith (2003a) conclusion of a bias of roughly 1.8 percent between 1940 and 1985 as excessive and making insufficient allowance for quality change.

30. Before 1983, the AHS was known as the Annual Housing Survey. We use only the new title in this work.

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 six such bins, and the 1985–present panel has nine. 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 percent 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 1975–1983 and 1985–present surveys make some variables noncomparable. 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, litter, and noise—were earmarked as bothersome instead of merely present, thereby making the measurement of these already difficult to measure characteristics nearly 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, litter, and noise problems unreliable. Our work includes these variables but focuses more on unmeasured quality change due to basic characteristic variables. Crone, Nakamura, and Voith (2003b) came to a similar conclusion with respect to the AHS's coverage of these variables.

At a late stage of this research, we determined that it was impossible to treat post-1985 as a single panel because of data discontinuities between 1995 and 1997. This accounts for the fact that our results are presented as three sets of regressions (1975–1983, 1985–1995, and 1997–2003) with no regressions spanning 1983–1985 and 1995–1997. As discussed in the text and tables, we use the CPI for those intervals, thus assuming that the CPI was an accurate measure of rent changes during those two pairs of years and hence biasing toward zero our final estimates of the difference between CPI growth and the growth of an alternative hedonic price index fully adjusted for quality, location, and subsidies. Further discussion of the background and reasons for the 1995–1997 data continuity can be found at http://www.huduser.org/intercept.asp?loc=/Datasets/ahs/docchg1997.pdf.

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 (Ruggles et al. 2003) provides easily accessible data sets and codebooks and maintains information on the comparability of each variable in their series over time. Compared to the AHS, Census data do 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.

Rent and age information are 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 very high level of explained variation seen in each of the Census regressions.

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