# Prices of Single-Family Homes since 1970: New Indexes for Four Cities

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By any measure, owner-occupied housing is a very large portion of national wealth. Of the 88.5 million occupied housing units in the United States in 1985, approximately 60 million were single-unit structures. The National Association of Realtors reports that the mean price of an existing single-family home in 1985 was $90,800. If that number is correct, the total value of the single-family housing stock in the United States that year was about $5.5 trillion. That same year, according to the Flow of Funds Accounts, total financial assets of the household sector were $7.9 trillion.

Although capital gains, including appreciation of house values, are not included in national saving as measured either in the national income and product accounts or in the flow of funds accounts, it can be argued that a full measure of national saving would include them. Assuming the figures above are correct, under such a definition a real increase of 2 percent in the value of single-family housing represents over $100 billion of private saving that is usually excluded from analyses of saving behavior and the saving rate. In 1985, personal saving (flow of funds basis) was $300.3 billion.

In 1983, 65 percent of all households owned their homes, and for most of those households the net equity in their homes represented the bulk of their net worth. A number of surveys have shown that nearly all homebuyers view their decision to buy at least in part as an investment decision. For homeowners the total return to their investment consists of the value of housing services, tax benefits, and net appreciation.

Despite their importance, we know surprisingly little about the movement of single-family home prices over the years. Through 1985, the U.S. Bureau of Labor Statistics calculated an index of increases in prices of existing homes, as a component of the CPI "home purchase" price index. The series was based on actual sales of properties financed with Federal Housing Administration (FHA) mortgages. The BLS index was widely criticized and has been discontinued.[1]

The only current data on existing home prices are published by the National Association of Realtors in its monthly report, *Home Sales*. That organization reports quarterly the median sales price of existing single-family homes for 54 metropolitan areas, based on reports from its members; the data have become an accepted and oft-cited source used by housing market analysts, the banking community, appraisers, and journalists.[2] The Association's median home prices are the only data on existing home prices reported by the U.S. Commerce Department in the annual *Statistical Abstract of the United States*. The data are also reported with great fanfare on the front pages of many daily newspapers each time they are released.

Unfortunately, the Association's data are not useful for purposes of analyzing the performance of the housing market or the movements of housing prices over many years. First, they have been reported only since 1981, making analysis over more than half of a business cycle impossible. Second, the change in median sales price is not a good measure of appreciation. As the Association itself points out, "Movements in sales prices should not be interpreted as measuring changes in the cost of a standard home. Prices are influenced by changes in cost and changes in the characteristics and size of homes actually sold."[3]

*The change in median sales price is not a good measure of appreciation. Characteristics of units sold may change from period to period.*

This paper uses data on recorded sales of nearly a million homes in four metropolitan areas—Atlanta, Chicago, Dallas, and San Francisco—to construct quarterly indexes of existing home prices between 1970 and 1986. We propose and apply a new method of constructing such indexes, which we call the "Weighted Repeat Sales" method. We believe the results give an accurate picture of the actual rate of appreciation in home prices in the four cities. The paper will explain the construction of the index, discuss the results, and compare them with National Association of Realtors' data for the period since 1981.

The availability of accurate data on housing price movements is important for another reason. An earlier article in this *Review* described how actual or reported increases in housing prices may affect the expectations of home buyers and sellers.[4] It was argued that such a process was in part the cause of the rapidly escalating prices in the Boston area between 1983 and 1986.

## *Housing Price Indexes: Repeat Sales vs. the Hedonic Approach*

The most significant problem with using changes in median sales price as a measure of appreciation is that the characteristics of the units sold may change from period to period. For example, if for some reason in a given period a disproportionate number of high-priced homes were sold, median price would rise even if no single property appreciated at all. In addition, as real incomes rise over time, the quality of new homes is likely to rise as well. Since those new homes ultimately become "existing" homes, the quantity and quality of existing housing purchased by the median buyer is also likely to increase over time. If it does, then median home price will rise even if individual properties are not appreciating.

To correct for this problem, two basic approaches have been used. First, a number of studies have used hedonic price indexes that statistically "control" for differences in the characteristics of units in various samples.[5] A second group of studies used data on properties that have actually sold more than once during the period in question.

The hedonic approach requires a large quantity of data on individual units sold, including their characteristics. The sales price is regressed on a set of variables that describe the unit—number of rooms, square feet of interior space, lot size, quality of construction, condition and so forth. The regression coefficients can be interpreted as implicit attribute prices. For example, the addition of a room may add $17,000 to the value of a property.

The hedonic approach can be used to construct a price index in two ways. First, a separate regression can be run on data from each time period. The estimated equations can then be used to predict the value of a "standard unit" in each period. The characteristics of the unit being valued, thus, do not change over the estimating period. This is a fixed-weight method similar to the one used to construct the Consumer Price Index. Alternatively, a single equation can be run on the pooled data from sales in all time periods. Inclusion of a time dummy for the period of the sale will allow the constant term to shift over time reflecting movement in prices, again controlling for characteristics.[6]

An alternative to the hedonic regression approach is to use data on properties that have actually sold more than once. Advocates of the repeat sales approach argue that it more accurately controls for characteristics of properties since it is based on observed appreciation of actual housing units.[7] The hedonic approach must first estimate the implicit value of each attribute. The precision of those estimates determines how well the hedonic equation actually controls and predicts. That depends in turn on how well the data capture the actual characteristics and quality of the unit. The repeat sales approach does not require the measurement of quality; it only requires that the quality of individual homes in the sample be constant over time.

The most important drawback to using the repeat sales method is that it wastes data. In most data sets, only a small percentage of all housing transactions appear more than once, and none of the data on single sales can be used. Moreover, it may be that the set of houses sold repeatedly is not representative of the general population of homes.[8]

This study overcomes many of the problems usually associated with the repeat sales method. First, the data sets in question are very large. In each of the four cities we identify many thousands of repeat sales. We lose very little precision by throwing out observations. Second, the time period—16.5 years—is long enough that we capture a large proportion of the housing stock. Almost all of our repeat sales are on properties that sold only twice. Properties that sold five or more times were excluded from the sample. Finally, since we had information on characteristics and quality of units, we were able to exclude observations when we knew that quality had changed between the first and second sales.

Another argument used to support the hedonic approach is that it allows for the identification of depreciation. The actual appreciation of an individual property is the difference between gross appreciation and any depreciation that occurs as the property ages. Several forces naturally tend to push down on housing prices over time. First, of course, is physical deterioration. Another is the change in tastes over time. The characteristics of houses match the preferences of people at the time of construction. Presumably, houses being built now capture today's tastes in a way that older homes do not. By including a variable for the construction date, the hedonic approach can capture the effect of the age of a unit on its value.

We would argue that it is not desirable to wash out all depreciation. The overall rate of return to an individual investment in a single-family house depends on many things—any explicit rent, imputed rent, tax benefits, and net appreciation. If we assume that a house is physically maintained so that physical deterioration is not the cause of the depreciation, then stylistic or even structural obsolescence should not be removed in calculating total appreciation. For investment purposes, a buyer/owner is interested in the net increase or decrease in value that is not the result of physical deterioration. Physical deterioration can be controlled, while most other causes of depreciation cannot. In our data set, we have a variable for "condition" that allows us to identify properties that have not been maintained. Those properties are excluded from the sample.

## *Construction of the Weighted Repeat Sales Indexes*

The basic data sets used to construct our Weighted Repeat Sales index contain large amounts of information (address, price, structural characteristics, condition, and so forth) on recorded sales of just under a million individual housing units between 1970 and 1986. Sample sizes are given in table 1. The data were gathered in four metropolitan areas: Atlanta, Chicago, Dallas, and San Francisco. The San Francisco data are actually drawn from the eastern part of the metropolitan area including Oakland, Berkeley, Piedmont, Hayward, and the rest of Alameda county. The data from the other three cities are drawn from the entire metropolitan areas. The data from Atlanta, Chicago, and Dallas, as well as data before 1979 from San Francisco, were obtained from the Society of Real Estate Appraisers Market Data Center in Atlanta. Property sales from the San Francisco area between 1979 and 1986 were obtained from the California Market Data Cooperative, a licencee of the Society.

The data were collected by members of the Society, who include many real estate agents, bank officers and appraisers. When a transaction occurs (at the closing), members fill out a long data sheet and submit it to the Society using a procedure similar to the one employed by the National Association of Realtors. We have no information about how representative the memberships of these groups are. Since the

Society of Real Estate Appraisers data cover a very large number of sales of both high-priced and low-priced properties, we assume that they are a representative group of transactions.[9]

Information on the sheets includes the exact street address of the property, the sales price, the closing date, and the type of financing, as well as between 25 and 40 characteristics of the property, depending on the city and the time period. To complete our data set, 16 separate files were merged.

### *Identifying Repeat Sales*

The process of identifying repeat sales involved several steps. First, an exact match was done on the address fields. Next, properties identified as anything other than a single-family home, such as a condominium or cooperative unit, were dropped. Third, pairs were excluded if there was evidence that the structure had been physically altered. This was done by checking the total number of rooms, the number of bedrooms, the indicated condition, and whether any rooms had been "modernized."

The condition and modernization variables were recorded differently in the various data sets that had to be merged. For condition, most used ratings of excellent, good, average, fair and poor. Because the ratings were subjective and given by different people, often many years apart, we decided to ignore small changes. Thus, a property that went from good to average was retained. Any property that indicated a jump of two categories between sales, such as a drop from good to fair, was excluded. All properties listed in poor condition in either period were excluded on the grounds that the rate of physical deterioration was likely to be high, and that there could well be unobservable problems reflected in price.

Whether the kitchen or a bathroom had been "modernized" was also recorded on the form in a variety of ways. Records where a modernized room was indicated were flagged and if a flag appeared at the time of the second sale but not at the first sale, the record was dropped.

A total of 39,267 clean pairs of sales were extracted. Of that number, 57 observations appeared to be data entry errors; the two sales prices differed by a factor closest to 10. The final sample sizes are listed in table 1. The richest sample was, not surprisingly, Chicago with 15,530 repeat sales. The smallest was Dallas with 6,669.

Table 1
*Data Base Used to Construct Weighted Repeat Sales Indexes 1970:I to 1986:III*

| | Number of Sales | Clean Pairs of Multiple Sales |
|---|---|---|
| Atlanta | 221,876 | 8,945 |
| Chicago | 397,183 | 15,530 |
| Dallas | 211,638 | 6,669 |
| San Francisco | 121,909 | 8,066 |
| Total | 952,606 | 39,210 |

Source: Society of Real Estate Appraisers Market Data Center Corp., Atlanta GA, and its licencee, The California Market Data Cooperative, Glendale CA.

### *The Weighted Repeat Sales Method*

This section contains a brief discussion of the econometric method used to construct the Weighted Repeat Sales index. The appendix contains greater detail and specific regression results.

The index construction we propose is a modification of the repeat sales housing index construction method of Bailey, Muth and Nourse.[10] Their method involves running a regression where the ith observation of the dependent variable is the log of the price of the ith house at its second sale date minus the log of its price on its first sale date. The independent variables consist only of dummy variables, one for each time period in the sample except for the first. For each house, the dummy variables are zero except for the dummy corresponding to the second sale (where it is $+1$) and for the dummy corresponding to the first sale (where it is $-1$). If the first sale was in the first period, there is no dummy variable corresponding to the first sale. The estimated coefficients are then taken as the log price index. (The value of the log price index at the first time period is zero; it is the base period for the index.)[11]

Such a method can be explained intuitively. A given pair of sales contains information on appreciation between the quarter of the first sale and the quarter of the second sale. The appreciation between two periods that is reflected in an index is the value of the index in the second period minus the value of the index in the first period. By including a negative dummy variable for the first sale and a positive dummy variable for the second sale, the regression chooses the values of the city index that minimize the sum of errors in predicting the appreciation of all the pairs in the sample.

Bailey, Muth and Nourse argued that their method of constructing price indexes from repeat sales data was more efficient than earlier repeat sales methods. If each observation of the dependent variable is equal to the change (over the interval between sales of that house) of a citywide log of the level of house prices, plus a house-specific noise term, and if this noise term is uncorrelated across houses and through time and it has a constant variance, then indeed, by the Gauss-Markov theorem, their log price index is the best linear unbiased estimate of the log of the citywide price level.

We disagree, however, with the assumption that the variance of the error term is constant across houses. We think that this variance is likely to be related to the interval of time between sales, and we shall show some evidence that this is so. There is likely to be a drift through time of individual house values due, for example, to random differences in the amount of upkeep expended across houses or random changes in neighborhood quality. With the original Bailey-Muth-Nourse method, homes sold after long time intervals have great influence on the index relative to homes sold over short time intervals. We thought such long time-interval observations should be given less weight in index construction. For the construction of our Weighted Repeat Sales index, we thus assumed that the log price of the ith house at time t is given by:

$$P_{it} = C_t + H_{it} + N_{it}$$

where $C_t$ is the log of the citywide level of housing prices at time t; $H_{it}$ is a Gaussian random walk (where $\Delta H_{it}$ has zero mean and variance $\sigma_h^2$) that is uncorrelated with $C_t$ and $H_{jt}$; $i \neq j$ for all t; and $N_{it}$ is a house-specific random error that has zero mean and variance $\sigma_N^2$ for all i and is serially uncorrelated.

Here, $H_{it}$ represents the drift mentioned above in individual housing value through time and $N_{it}$ reflects the random noise. What we want to estimate is the movement of C, the log of the citywide level of prices.

Consistent with these assumptions, our Weighted Repeat Sales method consists of three stages. In the first stage, the procedure of Bailey, Muth and Nourse is followed exactly, and a vector of regression residuals is calculated. In the second stage, a weighted regression of the squared residuals in the first stage is run with a constant term and the time interval between sales on the right-hand side. The constant term of the second-stage regression is an estimate of $2\sigma_N^2$, and the slope term is the estimate of $\sigma_h^2$. In the third stage a generalized least squares regression (weighted) is run by first dividing each observation in the first-stage regression by the square root of the fitted value in the stage-two regression and then running the stage-one regression again.

The detailed results of these procedures are discussed in the appendix. We now turn to a discussion of the indexes themselves. We are convinced that they present as accurate a picture as can be estimated of the citywide movement of prices of existing homes in the four areas studied.

## *Housing Prices in Four Cities: 1970 to 1986*

Charts 1a to 1d plot the Weighted Repeat Sales indexes, expressed in nominal and real terms, for the four cities. Table 2 summarizes the overall change in prices from the first quarter of 1970 to the second quarter of 1986. While substantial variance in performance can be seen across the cities, all saw home values at least keep pace with inflation as measured by the Consumer Price Index (CPI).

In Atlanta and Chicago, existing home prices remained remarkably constant in real terms over the 65 quarters of the sample period. While nominal prices nearly tripled, so did consumer prices in general. Real

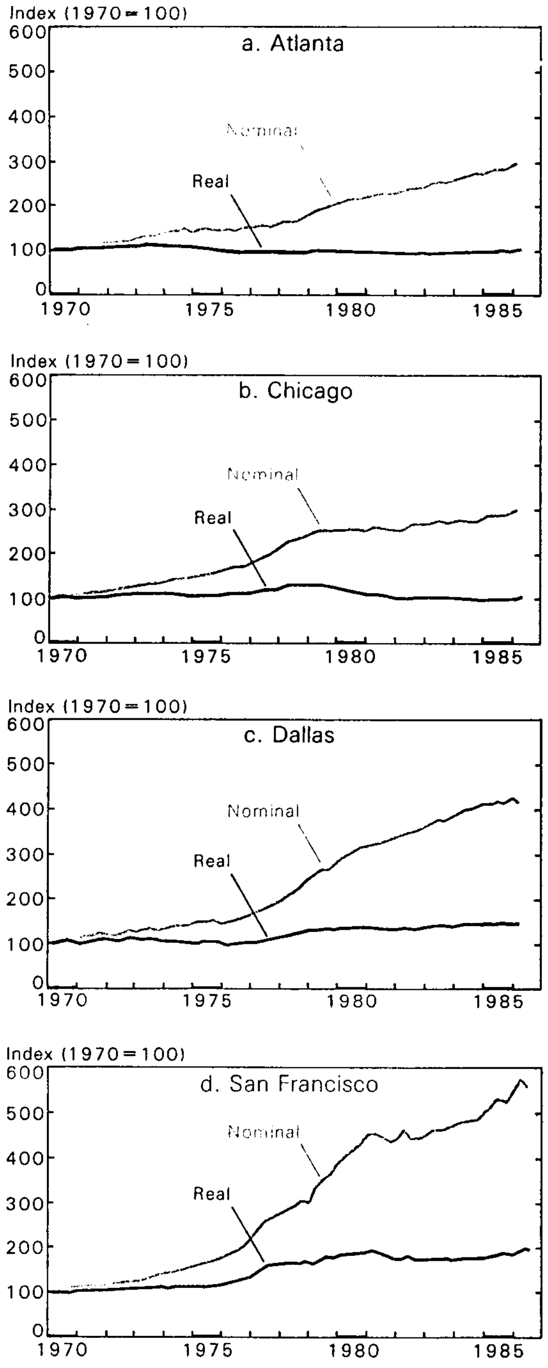
Table 2
*Changes in Prices of Existing Single-Family Homes, Computed Using the Weighted Repeat Sales Method 1970:I to 1986:II*
Percent

| | Nominal Change | | Real Change | |
|---|---|---|---|---|
| | Total | Average Annual Rate | Total | Average Annual Rate |
| Atlanta | +196.1 | +6.9 | +3.4 | +.2 |
| Chicago | +200.2 | +7.0 | +4.9 | +.3 |
| Dallas | +309.3 | +9.1 | +43.0 | +2.2 |
| San Francisco | +469.6 | +11.3 | +99.0 | +4.3 |
| CPI-U[a] | +186.2 | +6.7 | — | — |

[a]All Items, All Urban Consumers.

Chart 1

*Weighted Repeat Sales Indexes of Prices of Single-Family Homes*




Source: Authors' calculations.

increases in both Atlanta and Chicago averaged less than 1 percent per year.

The increases recorded in Dallas and San Francisco stand in marked contrast. Property values in Dallas rose an average of 2.2 percentage points per year faster than the CPI while real increases in San Francisco averaged 4.3 percent per year. Such high and sustained real appreciation rates are remarkable. Real home prices in Dallas increased by 43.0 percent. In San Francisco they nearly doubled.

Tables 3 and 4 look at two shorter periods of time. The first corresponds to the inflation/recession cycle of 1970:I to 1975:I. The second runs from the bottom of the 1974–75 recession to the period of very

Table 3

*Changes in Prices of Existing Single-Family Homes, Computed Using the Weighted Repeat Sales Method, 1970:I to 1975:I*

Percent

| | Nominal Change | | Real Change | |
|---|---|---|---|---|
| | Total | Average Annual Rate | Total | Average Annual Rate |
| Atlanta | +40.8 | +7.1 | +2.0 | +.4 |
| Chicago | +46.4 | +7.9 | +6.0 | +1.2 |
| Dallas | +39.2 | +6.8 | +.8 | +.2 |
| San Francisco | +53.8 | +9.0 | +11.4 | +2.2 |
| CPI-U[a] | +38.0 | +6.7 | — | — |

[a]All Items, All Urban Consumers

Table 4

*Changes in Prices of Existing Single-Family Homes, Computed Using the Weighted Repeat Sales Method, 1975:I to 1981:I*

Percent

| | Nominal Change | | Real Change | |
|---|---|---|---|---|
| | Total | Average Annual Rate | Total | Average Annual Rate |
| Atlanta | +55.9 | +7.7 | −6.8 | −1.1 |
| Chicago | +71.3 | +9.4 | +2.4 | +.4 |
| Dallas | +124.5 | +14.4 | +34.2 | +5.0 |
| San Francisco | +187.0 | +19.2 | +71.6 | +9.4 |
| CPI-U[a] | +67.2 | +8.9 | — | — |

[a]All Items, All Urban Consumers.

high interest rates in early 1981, a period when the baby-boom generation began to enter the housing market.[12]

Between 1970 and 1975, housing price increases were modest and fairly uniform. In all four cities, price increases totaled between 39 and 54 percent over the five years while prices in general rose 38 percent. San Francisco led the pack with real increases of 2.2 percent per year.

The period 1975:I to 1981:I shows anything but uniform housing price increases across the cities. The well-known California boom is evident. Over the six years, annual appreciation of homes in the San Francisco sample averaged 9.4 percent in real terms. Meanwhile, real prices in Atlanta dropped nearly 7 percent for an average decline of 1.1 percent per year.

While home prices in Chicago increased at about the same rate as consumer prices in general, Dallas was experiencing a boom of its own, less substantial than San Francisco's. Homes in Dallas appreciated 34.2 percent, or an average of 5.0 percent per year in real terms. The period from 1981 to 1986 will be discussed in the next section.

## *Comparisons with National Association of Realtors' Median Home Price*

The Weighted Repeat Sales indexes are compared with the median sales price of existing single-family homes, as published by the National Association of Realtors, in table 5 and charts 2a to 2d. Since the Realtors only began publishing data in the first quarter of 1981, the comparison is made for the period 1981:I to 1986:III. For Chicago and Dallas we have complete series from the first quarter of 1981 to the second quarter of 1986. The Association stopped publishing data on Atlanta in the third quarter of 1985 and did not publish figures for San Francisco in the first and second quarters of 1986. Thus, the Atlanta comparison stops in 1985 and the San Francisco comparison runs through the third quarter of 1986.

At the outset it is important to review what is being compared. The National Association of Realtors publishes the median sales price of existing single-family homes. That figure depends on the characteristics of homes that are sold in a given period as well as on the level of prices. The Association is careful to point out that its numbers are not meant to be used as an index of appreciation. Thus, the comparisons here should not be read as criticism of the Association or of its data. Despite the warnings of the Association, however, the popular press often interprets its figures as appreciation. In the past few years numerous headlines have announced the latest Association figures without carefully interpreting them.

Except for Chicago, the National Association of Realtors median price data increase significantly faster than the Weighted Repeat Sales indexes, indicating that for those three cities the "mix" effect is large. In

Table 5

*Changes in Weighted Repeat Sales Indexes and Changes in Median Prices of Existing Single-Family Homes in Four Cities, 1981–86*

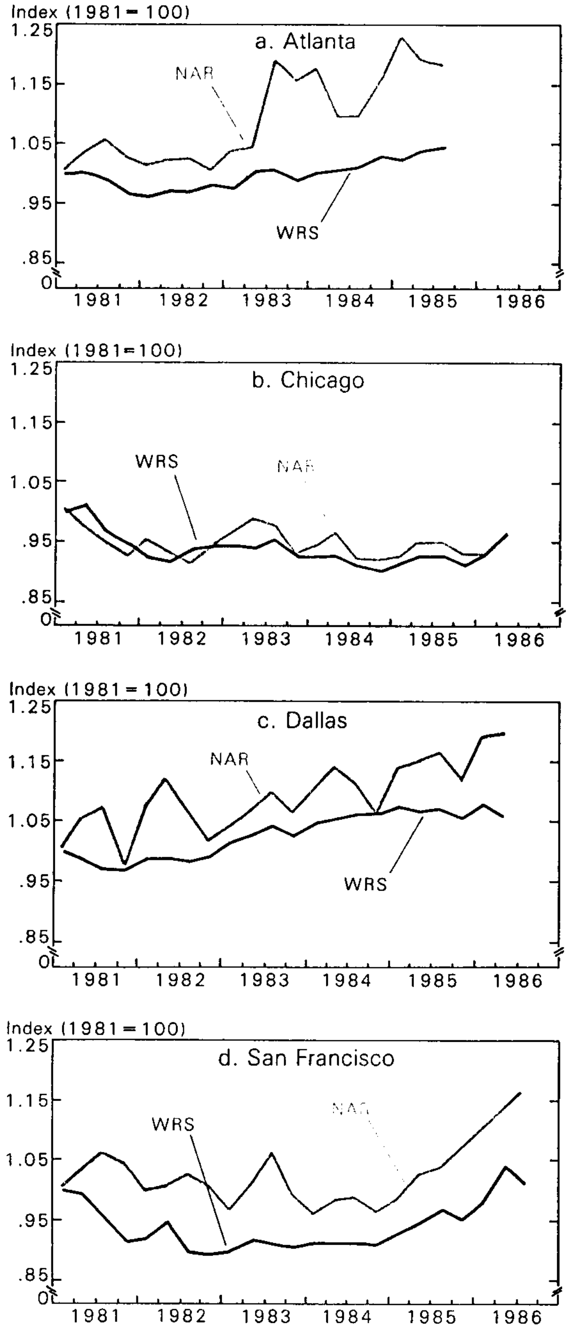
Percent

| | Change in Nominal Prices | | | | Change in Real Prices | | | |
|---|---|---|---|---|---|---|---|---|
| | National Assoc. Realtors | | Weighted Repeat Sales | | National Assoc. Realtors | | Weighted Repeat Sales | |
| | Total | Average Annual Rate | Total | Average Annual Rate | Total | Average Annual Rate | Total | Average Annual Rate |
| Atlanta[a] | +44.6 | +8.5 | +28.2 | +5.7 | +17.7 | +3.7 | +4.5 | +1.0 |
| Chicago[b] | +19.3 | +3.4 | +19.8 | +3.4 | −4.0 | −.8 | −3.4 | −.7 |
| Dallas[b] | +48.4 | +7.8 | +31.0 | +5.3 | +19.1 | +3.4 | +5.6 | +1.0 |
| San Francisco[c] | +45.4 | +7.0 | +25.8 | +4.3 | +16.2 | +2.8 | +.9 | +.2 |
| CPI-U[d] | +25.1 | +4.1 | | | | | | |

[a] 1981:1 to 1985:3
[b] 1981:1 to 1986:2
[c] 1981:1 to 1986:3
[d] All Items, All Urban Consumers.

Chart 2

*Price Indexes for Single-Family Homes: Weighted Repeat Sales vs. Median Sales Price*




(WRS) Weighted Repeat Sales index
(NAR) National Association of Realtors' median sales price
Source: Authors' calculations.

Atlanta, the Realtors Association data indicate that the median home price rose 44.6 percent between 1981 and 1985, while according to the Weighted Repeat Sales index, existing homes appreciated only 28.2 percent. In real terms at average annual rates, median price in Atlanta rose 3.7 percent per year, while the Weighted Repeat Sales index suggests that housing actually appreciated at a rate of only 1.0 percent per year, less than one-third as fast.

In San Francisco, the difference is most pronounced. The Realtors' Association data show 45.4 percent nominal growth over five and one-half years, while the Weighted Repeat Sales index shows only 25.8 percent appreciation. In real terms, the median price data show 2.8 percent annual growth, while our index indicates that the prices of individual properties increased only 0.2 percent per year in real terms. The real increase over the entire 5½-year period was less than 1 percent. In Dallas, the story is the same; the Realtors' Association median price data show a rise of 48.4 percent, while individual unit prices rose an average of only 31.0 percent.

In Chicago, however, the two series move together, as chart 2c shows. Both the Weighted Repeat Sales index and the index constructed from the Realtors' Association median price data show appreciation of 3.4 percent per year before adjusting for inflation. In real terms both indexes show average annual declines of just under 1 percent.

These results suggest that the mix of properties sold in Chicago from period to period has not changed, while the mix of properties sold in Atlanta, Dallas, and San Francisco from period to period has shifted, as you might predict, in favor of higher-value properties.

Table 6

*Income and Employment Growth, 1981–86*

Percent Change

| | Employment 1981:I–1986:I | Real Personal Income 1981–1984 |
|---|---|---|
| Atlanta | +27.4 | +20.1 |
| Chicago | −8.2 | +3.7 |
| Dallas | +25.4 | +19.1 |
| San Francisco | +3.9 | +11.0 |

Source: Data Resources, Inc. State and Area Forecasting Service.

A number of explanations are possible. Table 6 presents data on growth in employment and income for the four metropolitan areas between 1981 and 1986. While total employment grew 25 percent in Dallas, 27 percent in Atlanta and 4 percent in San Francisco, it fell more than 8 percent in Chicago. Real personal income grew about 20 percent in Dallas and Atlanta and 11 percent in San Francisco, but only 3.7 percent in Chicago. It is reasonable to expect the mix of homes sold to favor increasingly expensive properties when incomes are rising.

### *Seasonality*

The National Association of Realtors data seem to be more affected by seasonality than the Weighted Repeat Sales indexes. Neither series is seasonally adjusted. The Association states in its monthly publication, "There is a modest degree of seasonal variation in reported selling prices. Sales prices tend to reach a seasonal peak in July and then decline moderately over the next three months before experiencing a seasonal upturn."[13]

The third-quarter downturn is dramatic and consistent in the Dallas median price index (figure 2c) and quite pronounced in the median price data for San Francisco (figure 2d) and Chicago (figure 2b). And while it is slightly less evident in Atlanta, it is clearly present. Much less seasonality is shown by the Weighted Repeat Sales indexes. This suggests that most of the seasonal variation in median sales price is due to changes in the mix of homes sold and not to seasonal fluctuation in home values. If true, this is certainly important for buyers and sellers of homes to understand. It is consistent with notions of efficient markets.[14]

A third-quarter drop in median price due to a change in the mix of homes sold means that a higher portion of lower-value properties sell in the third quarter. If home purchase is associated with the school-year cycle as conventional wisdom suggests, then this could be true for at least two reasons. First, movers who coordinate their moves with the school cycle are likely to be families with children. Families with children buy more housing than families without children.

Second, an income effect is also possible. For example, two-parent families with children have household incomes more than twice as high as those of other households.[15] If, for any reason, those families or households that coordinate their moving with the school calendar have higher incomes than families or households that do not, then more high-value properties will be sold in the second quarter than in the third quarter, and median sales price will appear seasonal even if actual housing prices are not changing at all.

*Most of the seasonal variation in median sales price appears to be due to changes in the mix of homes sold and not to seasonal fluctuation in home values.*

### *Real Home Values Can and Do Fall*

It is important to note that the Weighted Repeat Sales data do show a number of prolonged periods of real decline in home values: Atlanta from 1973 to 1978; Chicago from 1979 to 1985; Dallas from 1972 to 1976; and San Francisco from 1980 to 1983. Nominal declines are, however, rare.

It has been argued that home prices are likely to be rigid or sticky downward in nominal terms, since people often pull their properties off the market when they cannot get "what the property is worth."[16] Many people predicted a crash in home prices in California in 1981. While real prices fell sharply, nominal prices fell only slightly.[17] The number of sales fell dramatically.

## *Conclusion*

In 1985, the value of the single-family housing stock was about two-thirds as large as the total value of all household financial assets. Changes in the value of single-family homes can have important implications for household saving behavior. Indeed, properly measured, household saving should include an estimate of net appreciation in home values.

This paper is an attempt to construct an accurate index of appreciation in the prices of single-family homes in four cities. We believe that the results are a first step toward filling an important gap in our understanding of housing markets and their effects on the rest of the economy.

In all four cities between 1970 and 1986, house values appreciated at least as fast as consumer prices were rising. The overall rate of appreciation varied substantially, however, over time and across cities. Over the 16 years of the sample period, we found annual real appreciation rates of 0.2 percent in Atlanta, 0.3 percent in Chicago, 2.2 percent in Dallas and 4.3 percent in San Francisco. Cross-city differences were most pronounced between 1975 and 1981, with real home values rising at a rate of 9.4 percent in San Francisco and falling at a rate of 1.1 percent in Atlanta.

Our results confirm that the changes in the median sales price of existing single-family homes are not a good measure of appreciation, despite their widespread use for that purpose. In three of the four cities, the median home price grew substantially faster than the actual appreciation indicated by our Weighted Repeat Sales indexes. In addition, median home price shows much more seasonal variation than our indexes.

What remains is to construct such indexes for more cities and to analyze their behavior over time. We hope that these first steps will stimulate further research and analysis.

## Appendix

As we reported in the text, a three-stage regression procedure is used to estimate the Weighted Repeat Sales indexes presented. In the first stage, the log price of the second sale minus the log price of the first sale is regressed on a set of dummy variables, one for each time period in the sample except the first. For each observation, the dummy is zero in every quarter except the quarters in which the two sales occurred. For the quarter of the first sale, the dummy is $-1$, and for the quarter of the second sale, the dummy is $+1$. From the first stage, a vector of residuals is calculated.

In the second stage, a weighted regression of the squared residuals from the first stage is run on a constant term and the time between sales. The constant term of the second-stage regression is an estimate of $2\sigma_N^2$, twice the variance of the house-specific random error. The slope coefficient is an estimate of the variance of the quarterly change in the Gaussian random walk term.

In the third stage, a generalized least squares regression (weighted) is run that repeats the stage-one regression after dividing each observation by the square root of the fitted value in the second stage.

The results of the three stages are described in the appendix table. The slope coefficients in the Stage II regressions are significant at the 1 percent level in all four cities. Both coefficients had the expected signs in all four cities. We conclude that the model provides a good estimate of the actual random error in individual selling price.

Note that the slope coefficients are large enough in all cases that the generalized least squares correction we employ will make a substantial difference to the results. For example, in the Atlanta regression, the slope coefficient is 0.00076. If a long time passed between sales of a particular home, say 50 quarters, the fitted value in this regression is 0.048, about five times the fitted value of the regression for a house for which the interval between sales was only one quarter, 0.0098. Thus, our method will give substantially less weight to observations with such long sales intervals than does the original Bailey, Muth, and Nourse method.

Changing the weight given to the observations has a substantial effect on the quarter-to-quarter change in the index. The correlation coefficients between the quarterly first difference of the Bailey-Muth-Nourse log index and the Weighted Repeat Sales log index is 0.984 for Atlanta, 0.975 for Chicago, 0.858 for Dallas, and 0.872 for San Francisco. The weights have less effect on the year-to-year change in the index; here the correlation between the two log indexes is 0.993 for Atlanta, 0.993 for Chicago, 0.969 for Dallas and 0.973 for San Francisco.

The results in the appendix table show that when a house is sold there is substantial noise in price that is unrelated to the interval between sales. An estimate of the standard deviation of this noise may be obtained by dividing the constant term in the Stage II regression by 2 (since the houses were sold twice) and taking the square root. The estimates of the sale-specific random error implied by data in the appendix table are quite consistent across the cities studied. For Atlanta, it is 7.00 percent; for Chicago, 6.78 percent, for Dallas, 6.33 percent; and for San Francisco, 5.38 percent. The estimates have small standard errors. It should be remembered that some of this variability in price is due to factors other than the noise in the sales process, such as unmeasured quality changes that take place between sales.

We calculated standard errors for the log index, for first differences of the log index, and for annual differences in the log index.[18] The level of the index is quite well measured, the first difference of the index is not terribly well measured, and the annual difference of the index is fairly well measured. One way of describing how well these variables are measured is to compute the ratio of the standard deviation of a variable to the average standard error for that variable. For the log index in levels, this ratio is 13.87 for Atlanta, 24.52 for Chicago, 9.94 for Dallas, and 28.03 for San Francisco. Thus, we can make satisfactory statements about the level of house prices in the cities. For the quarterly difference of the log indexes, the ratios are 1.64, 1.61,

## *Regression Results*

| | Atlanta | Chicago | Dallas | San Francisco |
|---|---|---|---|---|
| Number of Observations | 8,945 | 15,530 | 6,669 | 8,066 |
| Sample Period | 1970:1–1986:2 | 1970:1–1986:2 | 1970:1–1986:2 | 1970:1–1986:3 |
| Stage I<br>Ordinary Least Squares/Log Price | | | | |
| $R^2$ | .617 | .683 | .769 | .833 |
| SEE | .145 | .154 | .165 | .151 |
| Stage II<br>Weighted Regression<br>Stage I Residual Squared<br>on Time Interval | | | | |
| Constant | .0098<br>(.0009) | .0092<br>(.0004) | .0088<br>(.0008) | .0058<br>(.0007) |
| Coefficient on Interval | .00076<br>(.00027) | .00101<br>(.00013) | .00130<br>(.00024) | .00138<br>(.00021) |
| $R^2$ | .014 | .029 | .018 | .008 |
| SEE | .021 | .014 | .016 | .015 |
| Stage III<br>Weighted Regression<br>Log Price | | | | |
| $R^2$ | .442 | .517 | .599 | .640 |
| SEE | .988 | .979 | .986 | .990 |

See apendix text for a description of the regressions.

1.35, and 1.54, respectively. For the annual difference of the log index, the ratios are 2.73, 3.99, 2.90, and 3.62, respectively. We can make fairly accurate statements about the annual change in log housing prices.

The accuracy of the results for the quarter-to-quarter changes is disappointing. However, we doubt that it is possible to measure them with greater accuracy. Many housing price indexes purport to show monthly changes. Some of these indexes involve smoothing of data to produce reasonable-looking results.

The obvious way to test for the random-walk property of housing prices would be to take first differences in the indexes and check for serial correlation. If true housing prices are random walks, their first differences would be serially uncorrelated. However, the indexes are estimates of the true housing prices, and as such there is noise in them. Because of this house-specific noise, there may be serial correlation in the first differences of the index even if housing prices are random walks. There can be either positive or negative serial correlation, depending on the timing of the house sales of the houses that are used to make up the index.[19]

With our estimated (nominal) indexes, the estimated first-order serial correlation coefficient tends to be negative. If the quarter-to-quarter change in the log price index is regressed on the lagged quarter-to-quarter change and a constant term, then the coefficient of the lagged change is −0.351 for Atlanta, 0.240 for Chicago, −0.020 for Dallas, and 0.174 for San Francisco. The negative serial correlation is unaffected by the inclusion of quarterly seasonal dummies in the regression (and the seasonal dummies are, except for Chicago, statistically insignificant at the 5 percent level). The coefficient of the lagged quarter-to-quarter change in the regression with seasonal dummies is −0.351, 0.346, −0.028, and 0.197 respectively.

It was noted above that for quarterly differences the standard error of the estimate is large relative to the standard deviation of the quarterly difference itself. If the error in measuring the index is a stationary stochastic process, then its first difference must be negatively serially correlated, and hence the presence of this error might account for the negative serial correlation. Longer differences (which are measured better) tend to be positively correlated. If the one-year change $P_0 - P_{-4}$ is regressed on the one-year-lagged one-year change $P_{-4} - P_{-8}$, the coefficients on the lagged value are 0.218, 0.413, 0.449, and 0.349 respectively.

Despite the measurement error problems, we regard the Weighted Repeat Sales index we have constructed as very useful for the testing of market efficiency. In a companion study,[20] we run regressions of changes in prices of individual houses on lagged changes in the index. For each observation the lagged changes in the index are computed only from lagged data, from before the first sale of the individual house in that observation. Doing this necessitated estimating for each quarter the entire time series Weighted Repeat Sales index up to that quarter.

[1] An excellent analysis of the problems with the index can be found in John S. Greenlees, "An Empirical Evaluation of the CPI Home Purchase Index—1973–1978," *Journal of the American Real Estate and Urban Economics Association* (AREUEA Journal) vol. 10, no. 1, 1982, pp. 1–24.

[2] See National Association of Realtors, *Home Sales*, July 1987. The Association reports that in 1985, over 1.5 million reports were received from over 400 Boards of Realtors. The national figure for median home price is published monthly.

[3] Ibid., p. 2.

[4] Karl E. Case, "The Market for Single-Family Homes in Boston," *New England Economic Review*, May/June 1986.

[5] For a discussion of the hedonic technique, see Zvi Griliches, "Introduction: Hedonic Price Indexes Revisited," in Zvi Griliches, ed., *Price Indexes and Quality Change*, Harvard University Press, Cambridge, MA, 1971; Sherwin Rosen, "Hedonic Prices and Implicit Markets," *Journal of Political Economy*, January/February 1974; Peter T. Chinloy, "Hedonic Price and Depreciation Indexes for Residential Housing," *Journal of Urban Economics*, vol. 4, no. 4, October 1977, pp. 469–82; and especially, Raymond B. Palmquist, "Hedonic Price and Depreciation Indexes for Residential Housing: A Comment," *Journal of Urban Economics*, vol. 6, no. 2, April 1979, pp. 267–71; and Palmquist, "Alternative Techniques for Developing Real Estate Price Indexes," *Review of Economics and Statistics*, vol. 62, August 1980, pp. 442–80.

[6] The second approach has the disadvantage of constraining attribute prices to be the same in every period. The first method allows the individual attribute coefficients (implicit prices) to change each period.

[7] See, for example, Herman Wyngarden, "An Index of Local Real Estate Prices," *Michigan Business Studies*, vol. 1, no. 2, University of Michigan, Ann Arbor, 1927; Roy Wenzlick, "As I See the Fluctuations in the Selling Prices of Single-Family Residences," *The Real Estate Analyst*, December 24, 1952, pp. 541–8; and especially Martin J. Bailey, Richard F. Muth, and Hugh O. Nourse, "A Regression Method for Real Estate Price Index Construction," *Journal of the American Statistical Association*, December 1963, pp. 933–42.

[8] These points are made by Jonathan H. Mark and Michael A. Goldberg, "Alternative Housing Price Indices: An Evaluation," *AREUEA Journal*, vol. 12, no. 1, Spring 1984, pp. 30–49.

[9] A subset of the Society of Real Estate Appraisers' data was first used by Case to estimate the impact of Urban Homesteading on neighborhood properties in a study done for HUD. See Karl E. Case, "Housing Prices and Neighborhood Stabilization Policy." Report prepared for the Department of Housing and Urban Development, June 1979.

[10] Bailey, Muth, and Nourse, "A Regression Method for Real Estate Price Index Construction."

[11] This method is equivalent to another used in Case, "The Market for Single-Family Homes in Boston." If you assume that:

$$P_j = P_i (1+r_1)^{D_1}(1+r_2)^{D_2}(1+r_3)^{D_3} \ldots\ldots (1+r_n)^{D_n}$$

where $P_i$ = the initial sales price
$P_j$ = the second sales price
$r_t$ = rate of appreciation in period i and
$D_t$ = is a dummy variable which is equal to 1 if period i is between the first and last sales and 0 otherwise,

then the estimated coefficients are transformed into growth rates, $r_t$, that are then cumulated into an index that is identical to the Bailey, Muth, and Nourse index.

[12] For a good discussion of the demographics of housing demand, see *Housing Outlook Reports*, published every five years by the Joint Center for Urban Studies of MIT and Harvard University.

[13] *Home Sales*, August 1987, p. 92.

[14] For further discussion see Karl E. Case and Robert J. Shiller, "The Efficiency of the Market for Single-Family Houses," forthcoming 1987, available from the authors.

[15] U.S. Bureau of the Census, Current Population Reports, Series P–60, No. 146, *Money Income of Households, Families, and Persons in the United States: 1983*, U.S. Government Printing Office, Washington, D.C., 1985.

[16] Case, "The Market for Single-Family Homes in Boston."

[17] It may also be the case that actual sales price overstates the real purchase price if subsidized seller-financing is involved. It has been argued that take-back financing at subsidized rates disguised price declines in California in the early 1980s. Also, the degree of downward rigidity in nominal prices may not be independent of the inflation rate. Some argue that if inflation had not been high during the early 1980s California prices might have fallen in nominal terms.

[18] Data tables available upon request to Karl E. Case, Research Department, Federal Reserve Bank of Boston, Boston, MA 02106.

[19] Of course, since our data are in effect quarterly averages, we expect a serial correlation coefficient (and coefficient of the lagged value in the kind of autoregressions described below) of 0.25.

[20] Case and Shiller, "The Efficiency of the Market for Single-Family Houses."