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PRICES OF SINGLE FAMILY HOMES SINCE 1970: NEW INDEXES FOR FOUR CITIES

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New Indexes for Four Cities

ABSTRACT

This paper uses data on nearly a million homes sold 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 (WRS). We believe the results give an accurate picture of the actual rate of appreciation in home prices in the four cities. The paper explains the construction of the index, discusses the results and compares them with the National Association of Realtors data on the median price of existing single family homes for the period 1981 - 1986.

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INTRODUCTION

By any measure, owner occupied housing is a very large portion of national wealth. Of the total of 93.5 million housing units in the United States in 1984, 61.5 million were in single unit structures. The National Association of Realtors reports that the mean price of an existing single family home in 1984 was $86,000. If that number is correct, the total value of the single family housing stock in the United States that year was about $5.3 trillion. That same year, according to the Flow of Funds Accounts, total financial assets of the household sector were $6.6 trillion.

Since equity in owner occupied housing is a large portion of national wealth, any real appreciation in the value of single family homes is likely to make a significant contribution to national saving. Assuming the figures above are correct, a real increase of 2 percent in the value of owner occupied housing represents over $100 billion of private saving that is usually excluded from analyses of saving behavior and the saving rate. In 1984, personal saving (flow of funds basis) was $204.8 billion. Clearly, an accurate measure of national saving requires an accurate measure of appreciation in the value of owner occupied housing.

In 1983, 65 percent of all households owned their homes, and for most of those households the net equity in their homes represents the bulk of their net worth. A number of surveys have shown that nearly all home buyers 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 its importance, we know surprisingly little about the movement of single family home prices over the years. Through 1985, the BLS calculated an index of increases in existing home prices as a component of the CPI "home purchase" price index. The series was based on actual sales of properties that were financed with FHA mortgages. The BLS index was widely criticized and has been discontinued. An excellent analysis of the problems with the index is Greenlees [1978].

The only currently published source of data on existing home prices is the National Association of Realtors (NAR) monthly report, Home Sales. That organization reports the median price of existing single family homes quarterly for 54 metropolitan areas based on reports from its members; it has become an accepted and oft cited source used by housing market analysts, the banking community, appraisers and journalists. 1 NAR median home prices are the only

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1. See National Association of Realtors, "Home Sales," July, 1987. They report that in 1985, over 1.5 million reports were received from over 400 Boards of Realtors.

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data on existing home prices reported by the U.S. Commerce Department in the annual Statistical Abstract of the United States. They are also reported with great fanfare on the front pages of many daily newspapers when released each quarter.

Unfortunately, the Realtors' data are not useful for purposes of analysing the performance of the housing market or movements of housing prices over many years. First, they have only been reported 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 NAR 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." 2

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2. Ibid. pg 2

This paper uses data on nearly a million homes sold 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 -- hereafter referred to as the WRS method. We believe the results give an accurate picture of the actual rate of appreciation in home prices in the four cities. This paper will explain the construction of the index, discuss the results and compare them with the NAR data for the time period since 1981.

The availability of accurate data on housing price movements is important for another reason. It was argued in an earlier article (Case,[1986]) that actual or reported increases in housing prices may affect the expectations of home buyers and sellers. It was argued that such a process was in part the cause of the rapidly escalating prices in the Boston area from 1983 to 1986. In a companion paper, we use the WRS indexes to test for the efficiency of the housing market.

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. 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 did, then median home price would rise even if individual properties were 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.[3] A second

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3. For a discussion of the hedonic technique see Griliches [1971], Rosen [1974], Chinloy [1977] and especially Palmquist [1979].

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group of studies have 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. 4

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4. 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.

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. 5 The hedonic approach must first estimate the

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5. See for example Wyngarden [1927], Wenzlick [1952] and especially Bailey, Muth and Nourse [1963].

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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. That is, only a small percent of all housing transactions in most data sets reappear. None of the data on single sales is used. Moreover, it may be that the set of houses sold repeatedly is not representative of the general population of homes.6

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6. These points are made by Mark and Goldberg [1984]

This paper uses the repeat sales method for several reasons. 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 1/2 years -- is long enough that we capture units that sell more frequently and less frequently. 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.

One final argument that has been 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. There are forces that naturally tend to push down on housing prices over time. First, of course is physical deterioration. Another is that tastes may change over time. The characteristics of houses match the preferences of people at the time it was built. Presumably, new houses being built now capture today's tastes while older homes do not. By including a year built variable, the hedonic approach can capture the affect 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 <u>net</u> 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 <u>net</u> increase or decrease in value that is not the result of physical deterioration. Physical deterioration can be controlled. Most other causes of depreciation cannot.

In our data set, we have a variable for "condition" which allows us to identify properties that have not been maintained. Those properties are excluded from the sample.

<u>CONSTRUCTION OF THE WRS INDEXES</u>

The Data:

The basic data sets used to construct the WRS 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. 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 east 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 from before 1979 from San Francisco were obtained from the Society of Real Estate Appraisers (SREA) Market Data Center in Atlanta, Georgia. Property sales from the San Francisco area between 1979 and 1986 were obtained from the California Market Data Cooperative, a licencee of SREA.

The data were collected by members of the SREA 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 SREA. In this regard, the procedure is identical to the one employed by the National Association of Realtors. We have no information about how representative either the NAR or the SREA memberships are. Since the SREA data contain a very large number of sales, and since they contain data on

TABLE 1

DATA BASE USED TO CONSTRUCT
WEIGHTED REPEAT SALES INDEXES (WRS)

	TOTAL SALES	CLEAN 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.

thousands of sales of both high priced and low priced properties, we assume that they are a representative group of transactions.7

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7. A subset of the SREA data was first used by Case [1979] to estimate the impact of Urban Homesteading on neighborhood properties in a study done for HUD. Selection by Census tract found what seemed to be a uniform geographic distribution across the four cities being studied.

Information on the sheets includes the exact street address of the property, the sales price, the closing date, as well as between 25 and 40 characteristics of the property depending on the city and time period. To complete the data set we had to merge 16 separate files.

<u>Identifying</u> <u>Repeat</u> <u>Sales</u>: 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 a 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 number of total 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 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 well could 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 and one was not present 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 were different by close to a factor of ten. With those excluded, 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.

The WRS Method: This section contains a brief discussion of the econometric method used to construct the WRS 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 [1963] (hereafter, BMN). 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).[8]

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8. This method is equivalent to another used in Case [1986]. If you assume that:

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

where P_i = the initial sales price

P_j = the second sales price

r_t = rate of appreciation in period i

D_t = is a dummy variable which is equal to 1 if period i is between the first and last sales and 0 otherwise.

Using this method, the estimated coefficients are transformed growth rates, r_t, that are then cumulated into an index that is identical to the the BMN index.

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 city-wide log price level of houses 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 city-wide 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 BMN 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 purpose of our WRS construction, 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 city-wide level of housing prices at time t; H_{it} is a Gaussian random walk (where ΔH_{it} has zero mean and variance σ_h^2) that is uncorrelated with C_t and H_{it}, $i \neq j$ for all t; and N_{it} is a sale specific random error that has zero mean and variance σ_N^2 for all i and is serially uncorrelated.

Here, H_{it} represents the drift mentioned above in individual housing value through time. What we want to estimate is the movement of C, the city-wide level of prices.

Consistent with these assumptions, the WRS method consists of three stages. In the first stage, the BMN procedure 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 σ_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 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 city-wide movement of existing home prices for the four areas.

HOUSING PRICES IN FOUR CITIES: 1970 - 1986

Figure 1a-d plots the WRS indexes, nominal and real, 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 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 increases in both Atlanta and Chicago averaged less than one 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. Sustained real appreciation rates that high 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 1970:1 - 1975:1. The second runs from the bottom of the

TABLE 2

CHANGES IN PRICES OF EXISTING SINGLE FAMILY HOMES COMPUTED USING THE WEIGHTED REPEAT SALES (WRS) 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	+186.2	+6.7	-	-

FIGURE 1A

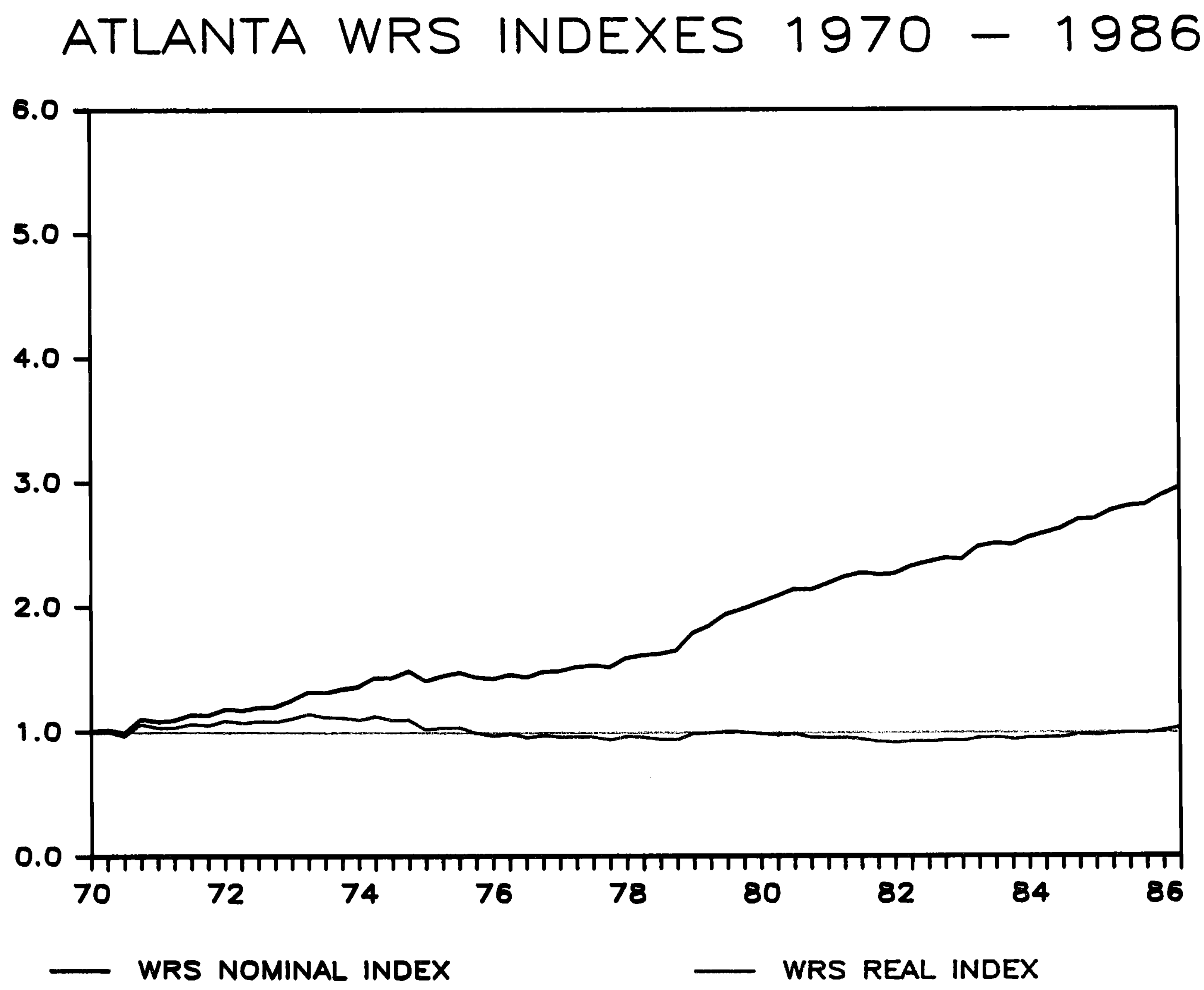

ATLANTA WRS INDEXES 1970 — 1986
6.0
5.0
4.0
3.0
2.0
1.0
0.0
70
72
74
76
78
80
82
84
86
WRS NOMINAL INDEX
WRS REAL INDEX

FIGURE 1B

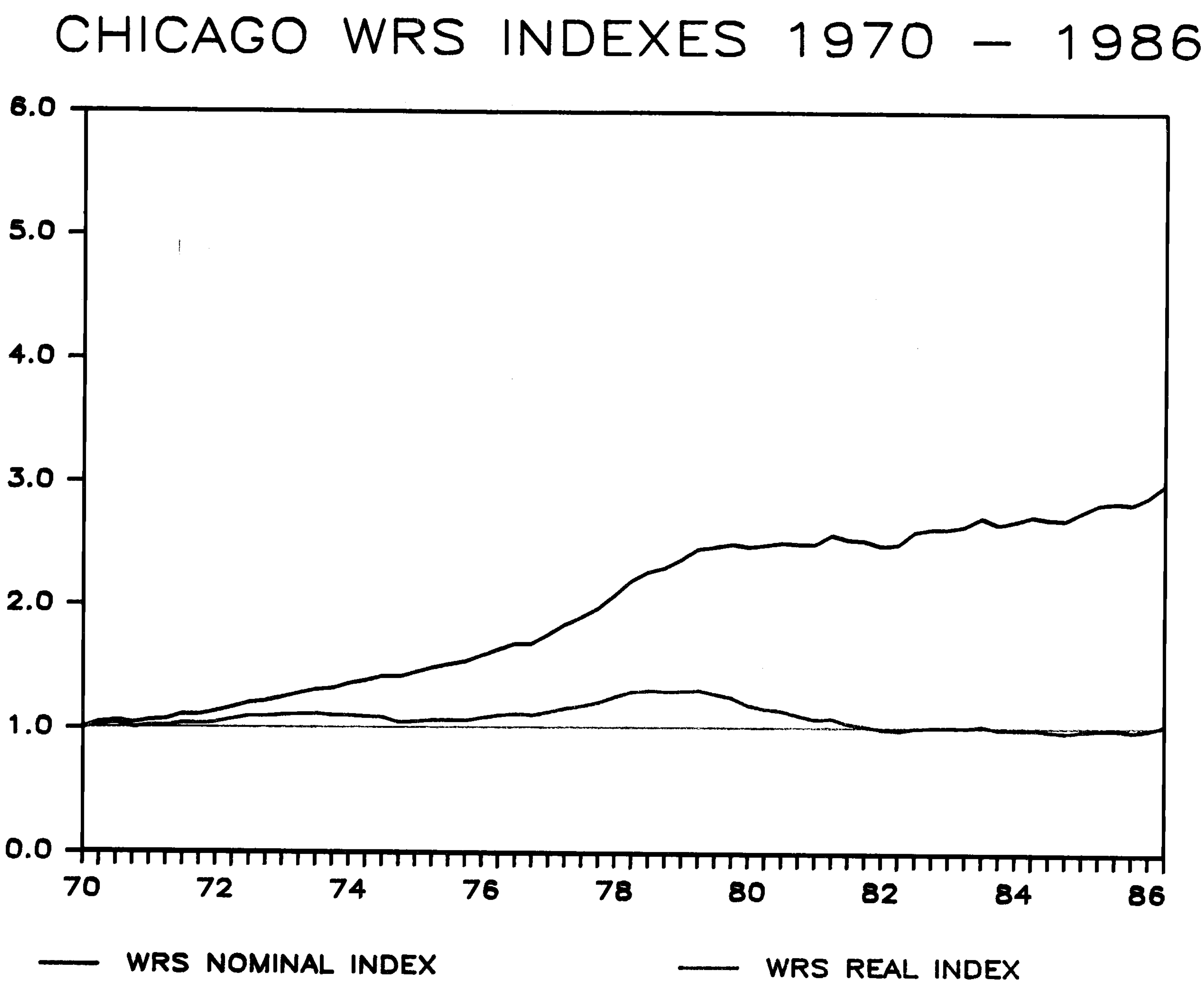
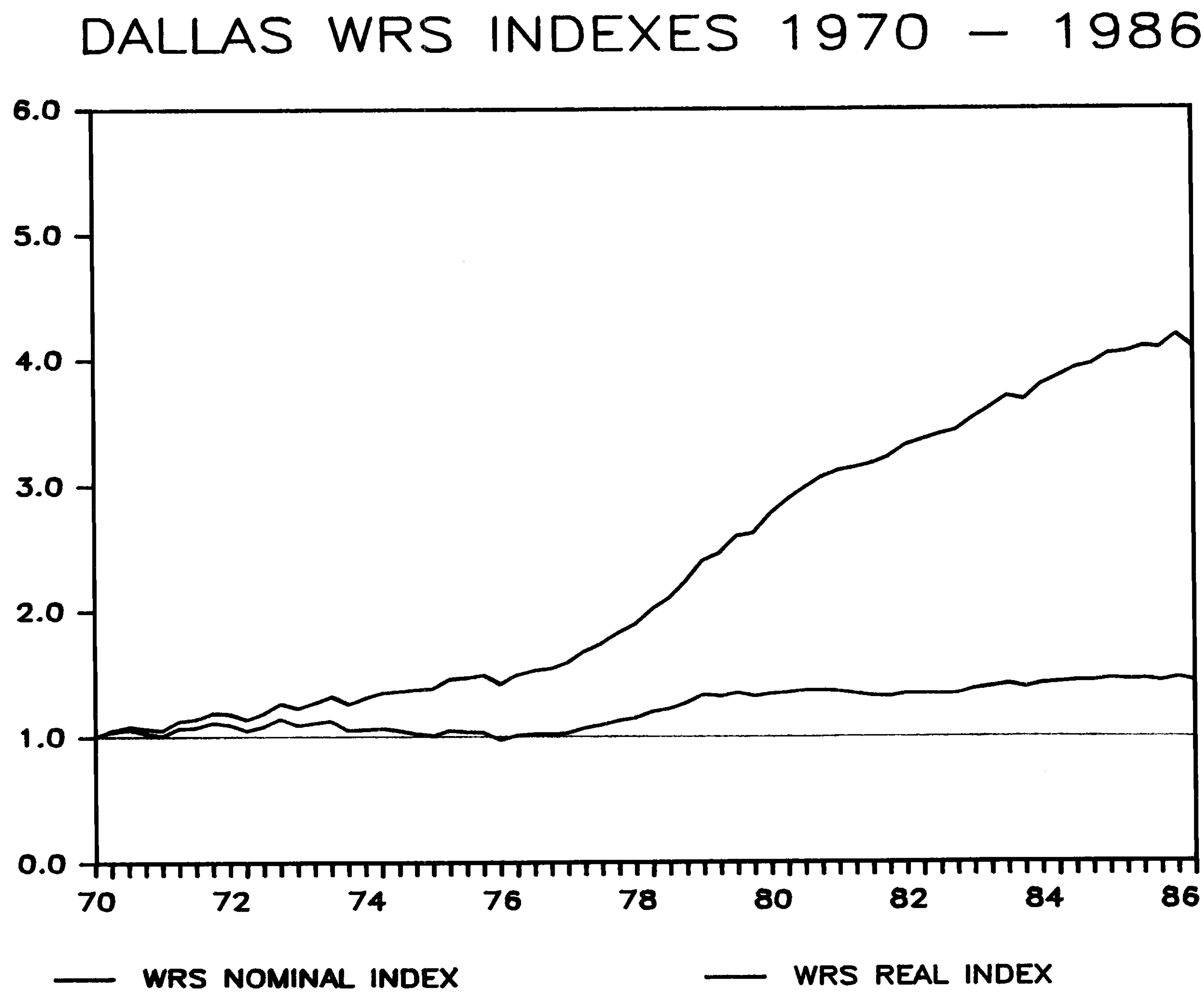

CHICAGO WRS INDEXES 1970 — 1986
6.0
5.0
4.0
3.0
2.0
1.0
0.0
70
72
74
76
78
80
82
84
86
WRS NOMINAL INDEX
WRS REAL INDEX

FIGURE 1C



DALLAS WRS INDEXES 1970 — 1986
6.0
5.0
4.0
3.0
2.0
1.0
0.0
70
72
74
76
78
80
82
84
86
WRS NOMINAL INDEX
WRS REAL INDEX

FIGURE 1D

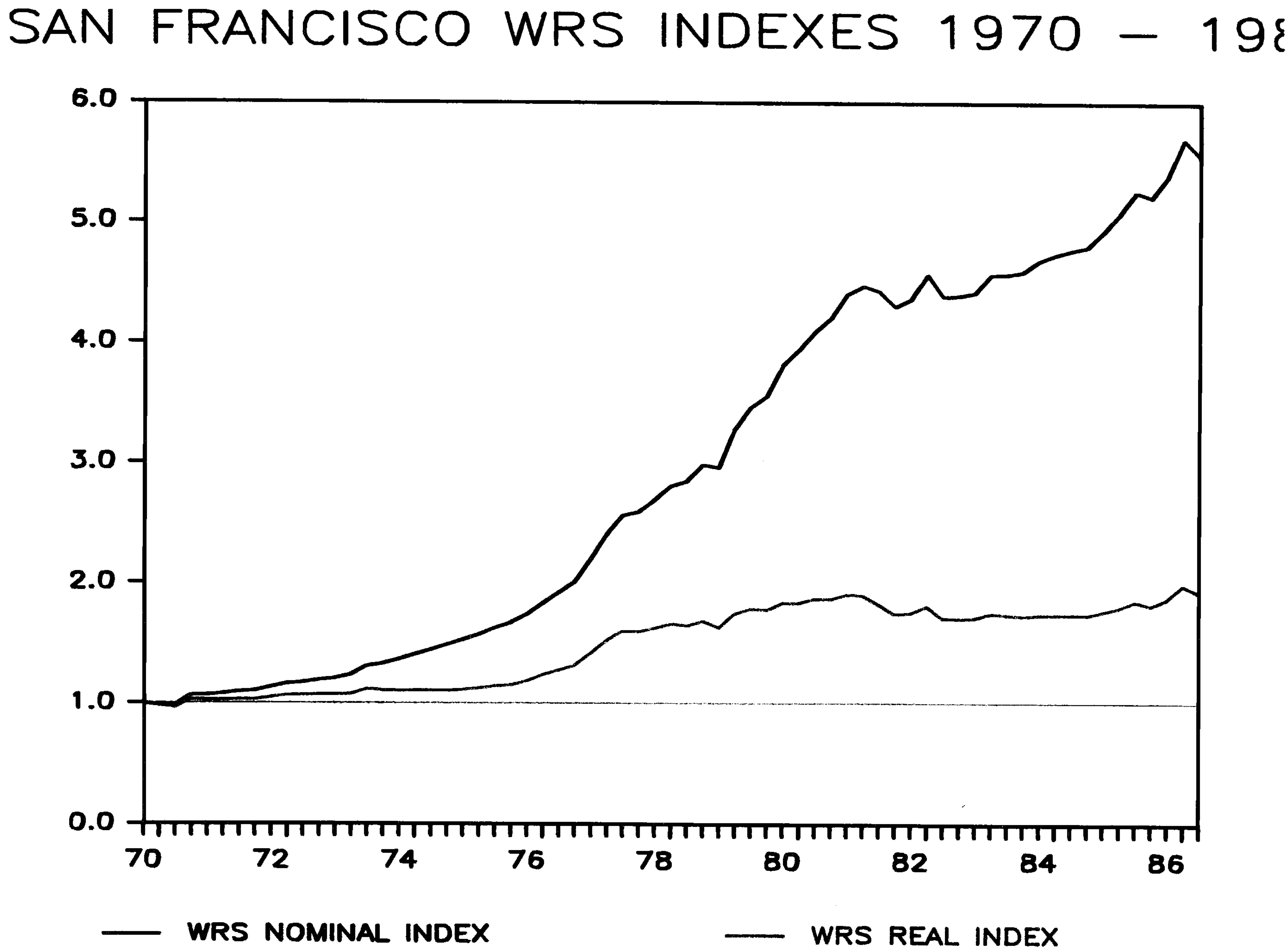

SAN FRANCISCO WRS INDEXES 1970 — 198
6.0
5.0
4.0
3.0
2.0
1.0
0.0
70
72
74
76
78
80
82
84
86
WRS NOMINAL INDEX
WRS REAL INDEX

TABLE 3

CHANGES IN PRICES OF EXISTING SINGLE FAMILY HOMES COMPUTED USING THE WEIGHTED REPEAT SALES (WRS) 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	+0.8	+.2
SAN FRANCISCO	+53.8	+9.0	+11.4	+2.2
CPI	+38.0	+6.7	-	-

TABLE 4

CHANGES IN PRICES OF EXISTING SINGLE FAMILY
HOMES COMPUTED USING THE WEIGHTED REPEAT SALES (WRS) 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	+67.2	+8.9	-	-

1974/1975 recession to the period of very high interest rates in early 1981. The later period was also one in which the baby-boom generation began to enter the housing market.9

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

Between 1970 and 1975, housing price increases were modest and fairly uniform. In all four cities, price increases totaled between 40 and 54 percent over the five years while prices in general rose 39 percent. San Francisco led the pack with real increases of 2.2 percent per year.

The six year period 1975:1 to 1981:1 show anything but uniform increases across the cities. First, of course, 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 were dropping nearly 7 percent -- an average of 1.1 percent per year.

While prices in Chicago increased at about the rate of inflation, Dallas was experiencing a boom of its own although not as substantial as San Francisco's. Homes in Dallas appreciated a total of 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.

Comparison with The National Association of Realtor's Data

Comparison of the WRS indexes with the median sales price of existing single family homes as published by the National Association of Realtors is presented in Table 5 and Figure 2a-d. Since the NAR only began publishing their data in the first quarter of 1981, the comparison is made for the period 1981 to 1986. For Chicago and Dallas we have complete series from the first quarter of 1981 to the second quarter of 1986. The NAR stopped publishing data on Atlanta in the third quarter of 1985 and did not publish a 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 NAR 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 NAR is careful to point out that their numbers are not meant to be used as an index of appreciation. Thus, the comparison should not be read as a criticism of the NAR or of its data.

Despite the warnings of the NAR, the popular press often interprets their figures as appreciation. The Boston Globe and the New York Times in the last few years have run numerous headlines announcing the latest figures from the NAR

TABLE 5
PERCENT CHANGES IN HOME PRICES:
COMPARISON OF WRS INDEX AND NATIONAL
ASSOCIATION OF REALTORS' MEDIAN PRICE OF
EXISTING SINGLE FAMILY HOMES

	NOMINAL				REAL			
	NAR	Average Annual Rate	WRS	Average Annual Rate	NAR	Average Annual Rate	WRS	Average Annual Rate
ATLANTA	+44.6	+8.5	+28.2	+5.7	+17.7	+3.7	+4.5	+1.0
CHICAGO	+19.3	+3.4	+19.8	+3.4	-4.0	-.8	-3.4	-.7
DALLAS	+48.4	+7.8	+31.0	+5.3	+19.1	+3.4	+5.6	+1.0
SAN FRANCISCO	+45.4	+7.0	+25.8	+4.3	+16.2	+2.8	+0.9	+0.2
CPI	+25.1	+4.1						

1. 1981:1 to 1985:3
2. 1981:1 to 1986:2
3. 1981:1 to 1986:3

FIGURE 2A

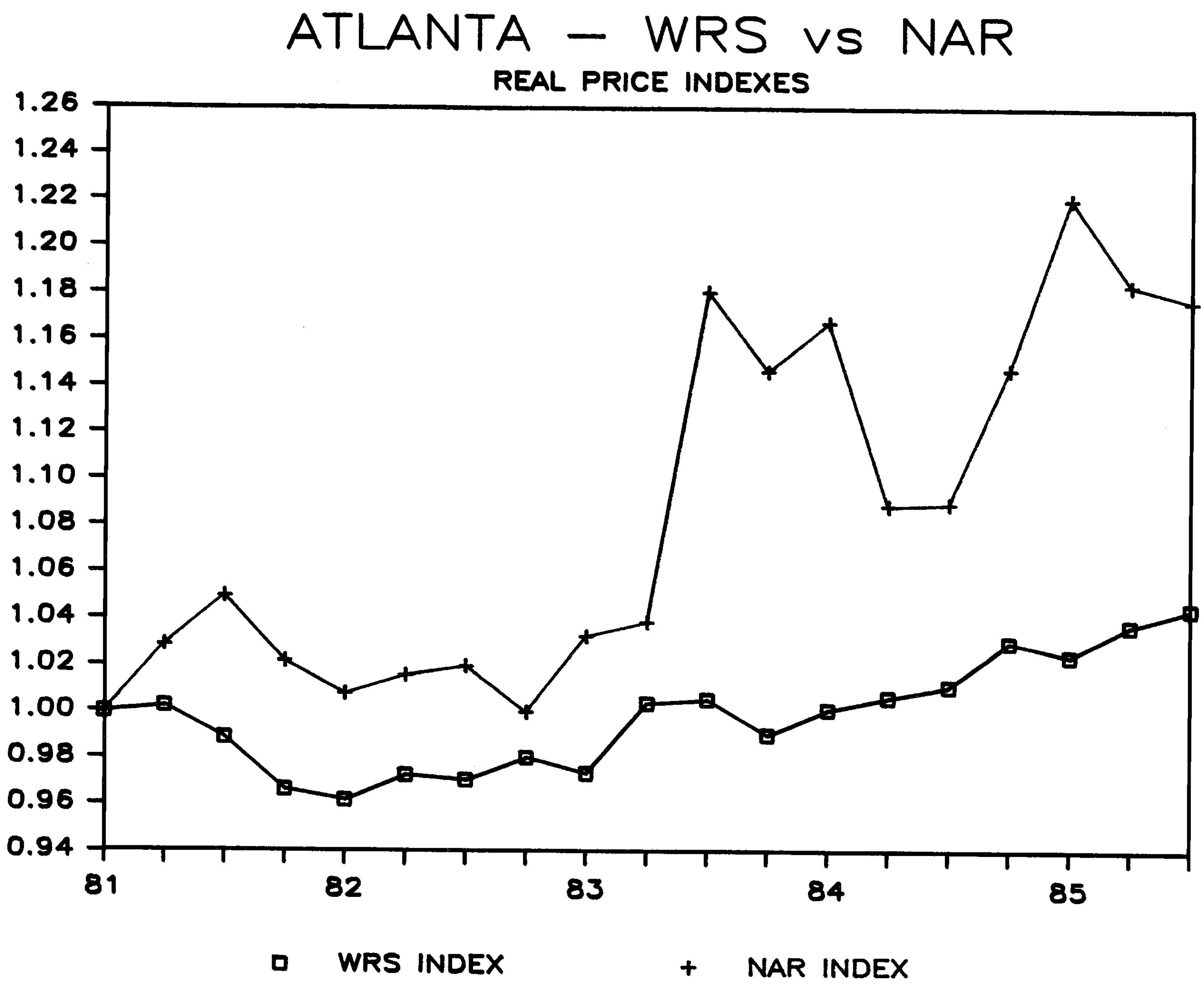

ATLANTA — WRS vs NAR
REAL PRICE INDEXES
1.26
1.24
1.22
1.20
1.18
1.16
1.14
1.12
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
0.94
81
82
83
84
85
WRS INDEX
NAR INDEX

FIGURE 2B

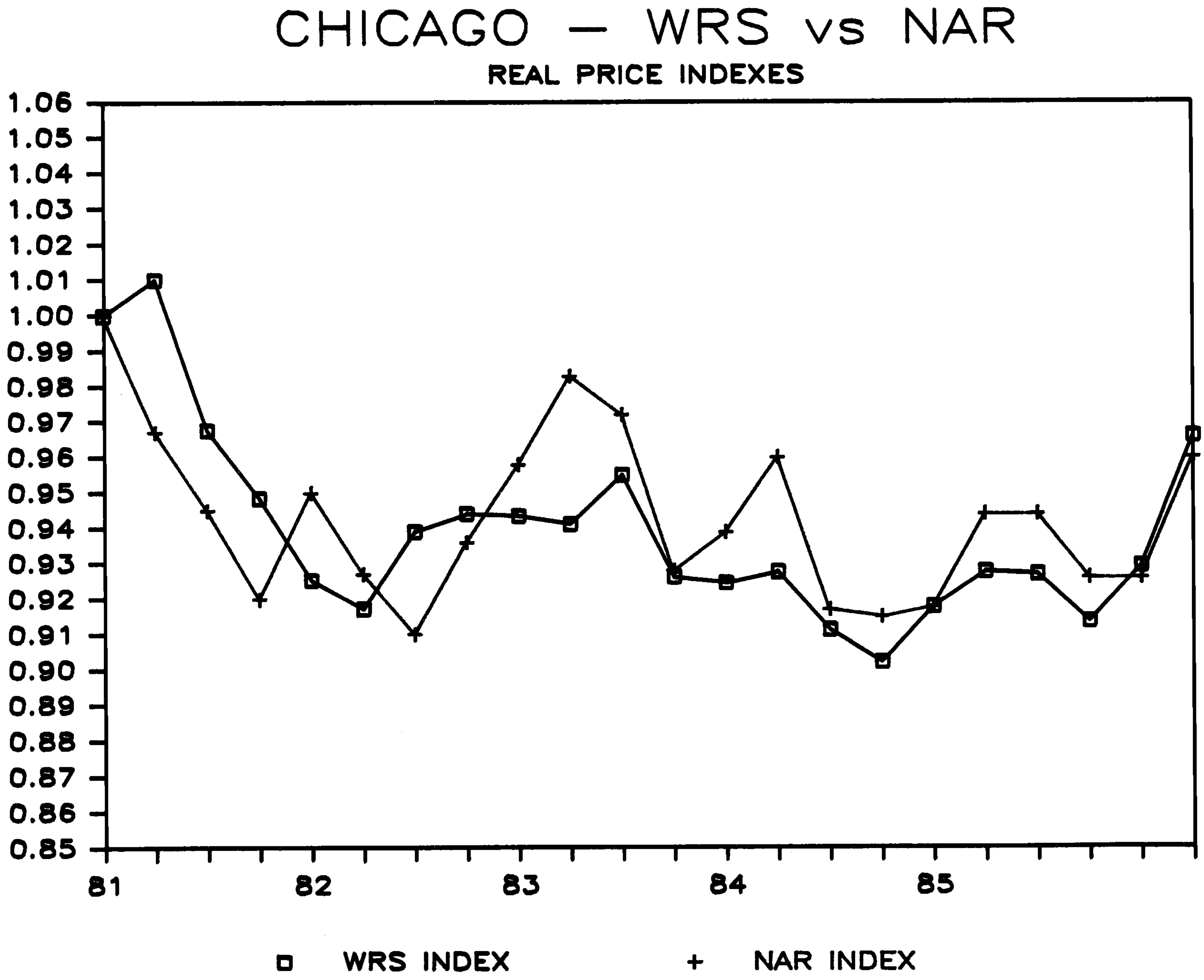

CHICAGO — WRS vs NAR
REAL PRICE INDEXES
1.06
1.05
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0.87
0.86
0.85
81
82
83
84
85
WRS INDEX
NAR INDEX

FIGURE 2C

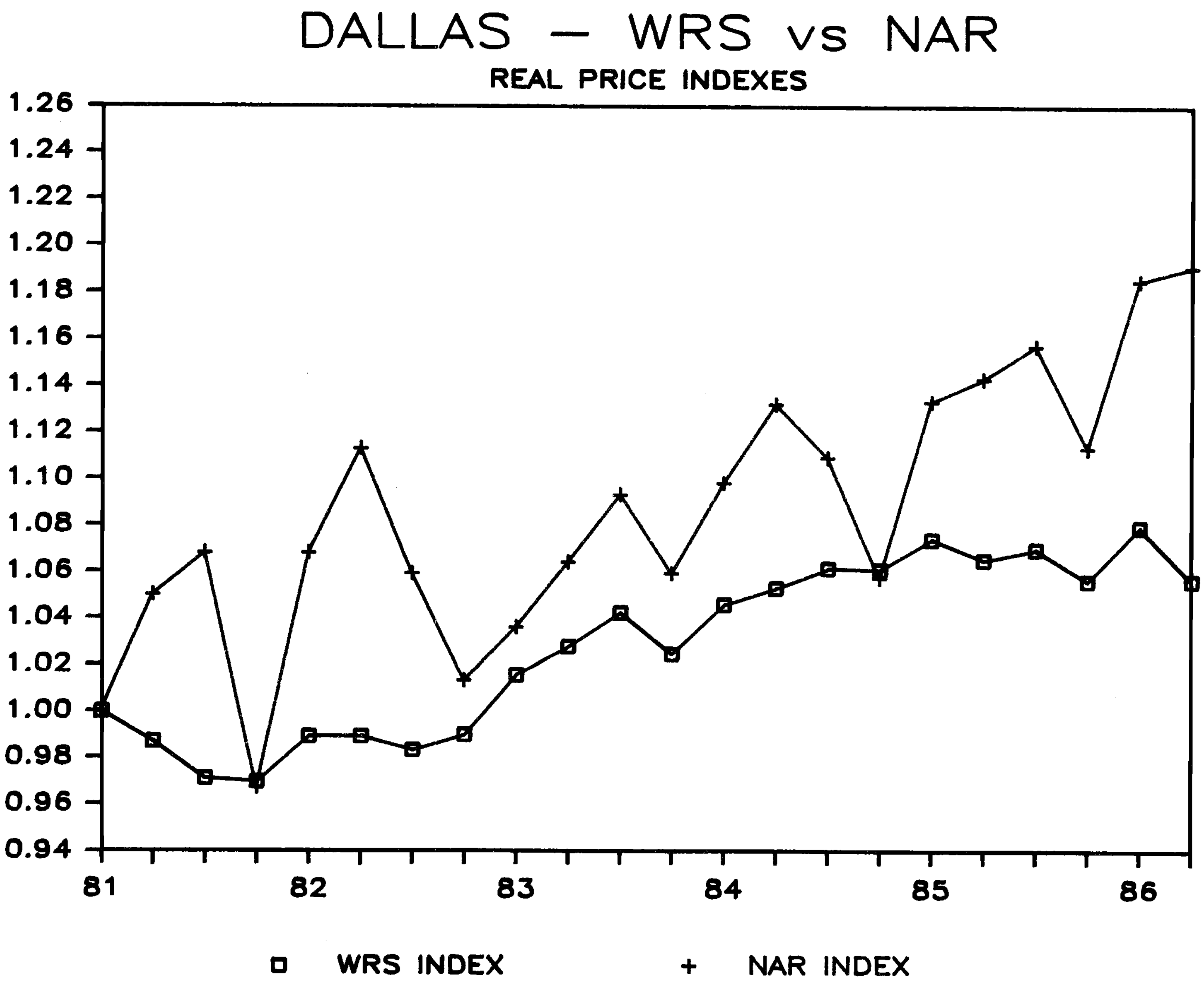
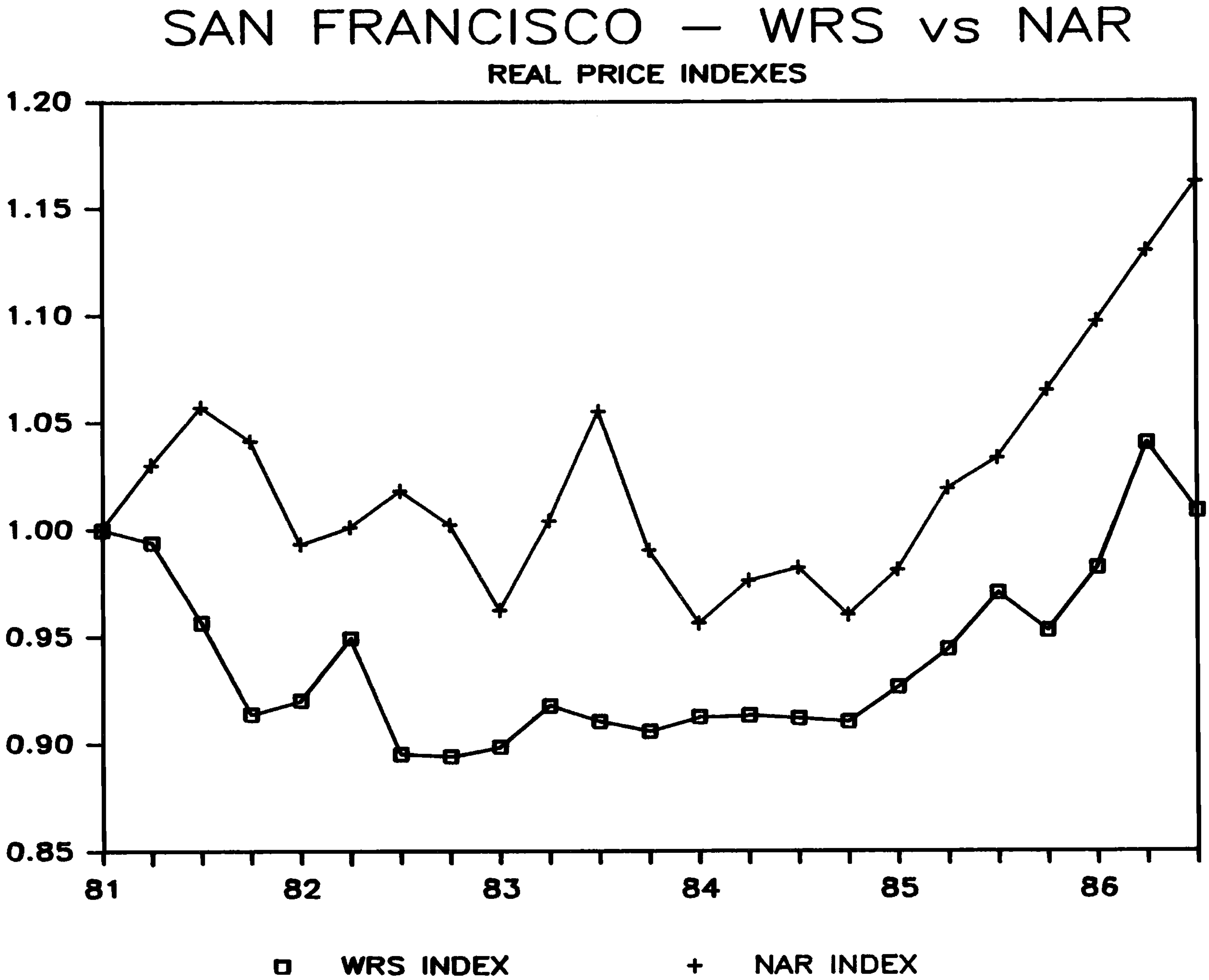

DALLAS — WRS vs NAR
REAL PRICE INDEXES
1.26
1.24
1.22
1.20
1.18
1.16
1.14
1.12
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
0.94
81
82
83
84
85
86
WRS INDEX
NAR INDEX

FIGURE 2D


SAN FRANCISCO — WRS vs NAR
REAL PRICE INDEXES
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
81
82
83
84
85
86
WRS INDEX
NAR INDEX

without carefully interpreting them.

Except for Chicago, the NAR data increase significantly faster than the WRS indexes, indicating that for those three cities the "mix" effect is large. In Atlanta, NAR median home price rose 44.6 percent between 1981 and 1985, while according to the WRS 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 housing actually appreciated at 1.0 percent per year, less than 1/3 as fast.

In San Francisco, the difference is most pronounced. The NAR data show 45.5 percent nominal growth over 5 1/2 years, while the WRS index shows only 25.8 percent appreciation. In real terms, the NAR data show 2.8 percent annual growth while our index indicates that property values increased only 0.2 percent per year in real terms. The real increase over the entire 5 1/2 year period was less than 1 percent. In Dallas, the story is the same. The NAR 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 very closely together. As Figure 2c shows, the lines cross in virtually every year. Both the WRS and NAR indexes show an increase 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.

While this paper is meant only to present and describe the data, a number of explanations are possible. Table 6 presents data on employment growth and income growth 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 over 8 percent in Chicago. At the same time while real personal income grew about 20 percent in Dallas and Atlanta and 11 percent in San Francisco, it only grew 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: Another interesting comparison between the NAR data and the WRS indexes is that the NAR data seem to have much more seasonality in them. Neither one of the series is seasonally adjusted. The NAR 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."

The third quarter downturn is dramatic and consistent in the Dallas NAR index (see Figure 2c) and quite pronounced in the median price data for San Francisco (Figure 2d) and Chicago (Figure 2b). While it is slightly less evident in

TABLE 6

INCOME AND EMPLOYMENT GROWTH
1981 - 1986

	%Ch in Employment 1981:1-1986:1	%Ch in 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

Atlanta, it is clearly present. Much less seasonality seems to be present in the WRS 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 due to seasonal fluctuation in home values. If true, this is certainly important for both home buyers and home sellers to know. It is consistent with notions of efficient markets.

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.

An income effect is also possible. For example, two parent families with children have household incomes more than twice as high as nonfamily households.10 If for any

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10. U.S. Dept. of Commerce, Bureau of the Census, Current Population Reports, Series P-60, No. 146

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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.

In addition, among people who do coordinate their moves with the school cycle, those with lower time values will search longer. Those with lower time value earn lower wages and, all else equal, are likely to buy less housing. Again, median home price will move seasonally because of seasonal differences in the mix even if values are not changing over the calendar.

Real Home Values Can and Do Fall

It is important to note that the WRS 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.

In his earlier piece, Case [1986] argued that home prices were 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." Many people predicted a crash in home prices in California in 1981. While real prices fell sharply, nominal prices fell only slightly. The number of sales fell dramatically. 11

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11. 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 1980's. Properties that indicated non-conventional financing were eliminated from our data.

FUTURE RESEARCH

We believe that we have carefully constructed as good an index of appreciation in single family home prices for our four cities as one can construct given the heterogeneity of the housing stock. What remains now is to analyse those series. Why do they behave the way that they do? Can we explain the sharp rises from 1975 to 1981? Were the California and Dallas booms in part "speculative bubbles?"

In a companion piece now being prepared, we will use several variations on the WRS index to test formally for the efficiency of the market for single family homes.

APPENDIX

As we reported in the text, a three step regression procedure was used to estimate the indexes presented. In the first stage, the log price of the second sale minus the log price of the first sale was regressed on a set of dummy variables, one for each time period in the sample except the first. For each observation the dummys are 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 $2\sigma_N^2$-- where σ_N^2 is 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 Table A1. The slope coefficients in the Step 2 regressions are signficant at the 1% level in all of the four cities. Both coefficients had the expected signs in all four cities. We

TABLE A1

REGRESSION RESULTS

	ATLANTA	CHICAGO	DALLAS	SAN FRANCISCO
Number of Observations	8945	15530	6669	8066
Sample Period	70:1 86:2	70:1 86:2	70:1 86:2	70:1 86:3
<u>Stage I</u> OLS/Log Price				
R^2	.617	.683	.769	.833
SEE	.145	.154	.165	.151
<u>Stage II</u> Weighted Regression Stage I Residual Squared on Time Interval				
Constant	.0098 (.0009)	.0092 (.0004)	.0088 (.0008)	.0058 (.0007)
Coef. on Interval	.00076 (.00027)	.00101 (.00013)	.00130 (.00024)	.00138 (.00021)
R^2	.014	.029	.018	.008
SEE	.021	.014	.016	.015
<u>Stage III</u> Weighted Regression Log Price				
R^2	.442	.517	.599	.640
SEE	.988	.979	.986	.990

See text for a description of the regressions.

conclude that the model provides a good estimate of the random error in individual selling price.

Note that the 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 .00076. If a long time passed between sales of a particular home, say 50 quarters, the fitted value in this regression is .048, about five times the fitted value of the regression for a house for which the interval between sales was only a one quarter, .0098. Thus, our method will give substantially less weight to such long sales interval data than does the original BMN 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 BMN log index and the WRS log index is .984 for Atlanta, .975 for Chicago, .858 for Dallas, and .872 for San Francisco. There is less effect of the weights on the year to year change in the index, here the correlation between the BMN log index and the WRS log index is .993 for Atlanta, .993 for Chicago, .969 for Dallas and .973 for San Francisco.

The results in Table 1A 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 step 2 regression by 2 (since the houses were sold twice) and taking the square root. The estimates of implied by Table A1 are quite consistent across the cities studied. For Atlanta, it is 7.00%; for Chicago, 6.78%, for Dallas, 6.33%; and for San Francisco, 5.39%. 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. Some of this is due to unmeasured quality changes that take place between sales.

Table A2 a-d present coefficeints and standard errors for all four cities. We calculated standard errors for the log index, for first differences of the log index, and for annual differences in the log index. 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/Oakland. Thus, we can make satisfactory statements about the level of house prices in the cities. For the quarterly difference of the log indexes, the ratio is 1.64, 1.61, 1.35, and 1.54 respectively. For the annual difference of the log index, the ratio is 2.73, 3.99, 2.90, and 3.62 respectively. We can make fairly accurate statements about the annual change in

Table 2A
Atlanta Price Indexes and Standard Errors

Quarter	Index	B=log (Index/100)	SE(b)	$SE(b-b_{-1})$	$SE(b-b_{-4})$
1970.1	100.00000	0.00000	0.00000	0.00000	0.00000
1970.2	101.88780	0.01870	0.04809	0.04809	0.00000
1970.3	99.11944	-0.00884	0.05428	0.06667	0.00000
1970.4	110.64814	0.10119	0.02777	0.05385	0.00000
1971.1	108.39499	0.08061	0.02368	0.02235	0.02368
1971.2	109.89158	0.09432	0.02296	0.01685	0.04513
1971.3	114.35474	0.13414	0.02377	0.01701	0.05191
1971.4	113.68083	0.12822	0.02432	0.01896	0.02375
1972.1	118.82442	0.17248	0.02456	0.02014	0.01867
1972.2	117.47698	0.16107	0.02333	0.01924	0.01714
1972.3	120.39917	0.18564	0.02294	0.01760	0.01677
1972.4	120.81061	0.18905	0.02373	0.01709	0.01875
1973.1	125.57426	0.22773	0.02422	0.01821	0.01952
1973.2	132.36256	0.28037	0.02288	0.01741	0.01697
1973.3	131.78065	0.27597	0.02514	0.01869	0.01931
1973.4	134.76323	0.29835	0.02654	0.02260	0.02062
1974.1	136.48929	0.31108	0.02356	0.02174	0.01907
1974.2	143.77132	0.36305	0.02299	0.01720	0.01527
1974.3	143.82816	0.36345	0.02387	0.01636	0.01960
1974.4	149.27959	0.40065	0.02570	0.02064	0.02354
1975.1	140.84004	0.34245	0.02654	0.02359	0.02182
1975.2	145.15168	0.37261	0.02380	0.02117	0.01661
1975.3	147.90584	0.39141	0.02438	0.01843	0.01858
1975.4	143.90206	0.36396	0.02620	0.02121	0.02317
1976.1	142.68338	0.35546	0.02526	0.02255	0.02304
1976.2	146.40004	0.38117	0.02265	0.01871	0.01660
1976.3	143.85972	0.36367	0.02254	0.01469	0.01694
1976.4	148.73213	0.39698	0.02297	0.01512	0.02008
1977.1	149.24831	0.40044	0.02319	0.01592	0.01893
1977.2	152.62821	0.42283	0.02211	0.01451	0.01405
1977.3	153.98732	0.43170	0.02181	0.01202	0.01331
1977.4	152.16687	0.41981	0.02213	0.01228	0.01432
1978.1	159.89837	0.46937	0.02194	0.01230	0.01408
1978.2	162.12910	0.48322	0.02176	0.01145	0.01215
1978.3	163.02037	0.48870	0.02183	0.01149	0.01166
1978.4	165.93469	0.50642	0.02217	0.01195	0.01251
1979.1	180.00568	0.58782	0.02129	0.01093	0.01056
1979.2	186.19476	0.62162	0.02097	0.00810	0.00979
1979.3	195.10236	0.66835	0.02097	0.00736	0.00965
1979.4	199.10934	0.68868	0.02137	0.00809	0.01102
1980.1	204.37468	0.71478	0.02148	0.00909	0.00921
1980.2	209.23304	0.73828	0.02156	0.00966	0.00876
1980.3	215.17788	0.76629	0.02107	0.00844	0.00739
1980.4	214.28667	0.76214	0.02143	0.00806	0.00928
1981.1	219.59922	0.78663	0.02145	0.00907	0.00947
1981.2	224.70513	0.80962	0.02120	0.00855	0.00911
1981.3	227.84585	0.82350	0.02145	0.00850	0.00840
1981.4	226.32211	0.81679	0.02173	0.00975	0.00988
1982.1	227.29909	0.82110	0.02167	0.01000	0.00970
1982.2	233.10042	0.84630	0.02163	0.00990	0.00914
1982.3	236.60896	0.86124	0.02154	0.00969	0.00949
1982.4	239.78839	0.87459	0.02173	0.00979	0.01050
1983.1	238.35848	0.86861	0.02126	0.00920	0.00920
1983.2	248.65580	0.91090	0.02127	0.00801	0.00911

1983.3	251.50043	0.92227	0.02122	0.00799	0.00900
1983.4	250.06258	0.91654	0.02146	0.00846	0.00989
1984.1	256.10918	0.94043	0.02119	0.00848	0.00817
1984.2	260.04971	0.95570	0.02116	0.00756	0.00813
1984.3	263.63100	0.96938	0.02135	0.00786	0.00838
1984.4	270.69019	0.99580	0.02165	0.00883	0.00968
1985.1	271.36298	0.99829	0.02134	0.00893	0.00821
1985.2	278.01922	1.02252	0.02132	0.00803	0.00821
1985.3	281.58993	1.03528	0.02134	0.00817	0.00852
1985.4	282.53935	1.03865	0.02181	0.00939	0.01034
1986.1	290.26413	1.06562	0.02178	0.01021	0.00953
1986.2	296.06943	1.08542	0.02347	0.01342	0.01309

Table 2B

Chicago Price Indexes and Standard Errors

Quarter	Index	B=log (Index/100)	SE(b)	$SE(b-b_{-1})$	$SE(b-b_{-4})$
1970.1	100.00000	0.00000	0.00000	0.00000	0.00000
1970.2	104.67217	0.04566	0.01399	0.01399	0.00000
1970.3	106.99719	0.06763	0.01449	0.01226	0.00000
1970.4	104.44545	0.04349	0.01538	0.01302	0.00000
1971.1	107.29178	0.07038	0.01357	0.01185	0.01357
1971.2	107.91697	0.07619	0.01318	0.00948	0.01072
1971.3	111.75306	0.11112	0.01346	0.00929	0.01112
1971.4	111.72732	0.11089	0.01425	0.01045	0.01277
1972.1	114.37638	0.13432	0.01328	0.01027	0.00958
1972.2	117.72623	0.16319	0.01314	0.00869	0.00876
1972.3	121.39746	0.19390	0.01320	0.00848	0.00922
1972.4	122.55089	0.20336	0.01346	0.00877	0.01047
1973.1	125.58212	0.22779	0.01279	0.00810	0.00827
1973.2	129.03453	0.25491	0.01273	0.00712	0.00783
1973.3	132.02491	0.27782	0.01381	0.00865	0.00952
1973.4	133.20609	0.28673	0.01485	0.01139	0.01117
1974.1	137.34033	0.31729	0.01321	0.01067	0.00792
1974.2	139.57940	0.33346	0.01308	0.00823	0.00744
1974.3	143.07692	0.35821	0.01358	0.00878	0.00980
1974.4	142.11075	0.35144	0.01418	0.01042	0.01204
1975.1	146.35356	0.38086	0.01336	0.00995	0.00866
1975.2	149.89936	0.40479	0.01291	0.00812	0.00777
1975.3	152.56708	0.42243	0.01280	0.00717	0.00840
1975.4	155.13984	0.43916	0.01330	0.00782	0.01007
1976.1	160.28258	0.47177	0.01276	0.00780	0.00785
1976.2	164.87910	0.50004	0.01265	0.00660	0.00696
1976.3	169.04881	0.52502	0.01271	0.00644	0.00682
1976.4	169.37905	0.52697	0.01287	0.00673	0.00799
1977.1	176.92073	0.57053	0.01260	0.00653	0.00645
1977.2	185.13668	0.61592	0.01259	0.00598	0.00623
1977.3	190.98558	0.64703	0.01248	0.00572	0.00611
1977.4	198.13102	0.68376	0.01271	0.00589	0.00679
1978.1	209.08801	0.73759	0.01259	0.00618	0.00605
1978.2	220.91683	0.79262	0.01271	0.00623	0.00621
1978.3	227.73012	0.82299	0.01261	0.00603	0.00582
1978.4	231.22864	0.83824	0.01270	0.00593	0.00646
1979.1	238.36482	0.86863	0.01278	0.00630	0.00633
1979.2	246.89529	0.90379	0.01288	0.00683	0.00677
1979.3	248.31439	0.90953	0.01302	0.00727	0.00687
1979.4	250.74884	0.91928	0.01630	0.01222	0.01205
1980.1	248.50291	0.91028	0.04700	0.04683	0.04573
1980.2	250.13204	0.91682	0.01771	0.04732	0.01413
1980.3	252.01174	0.92431	0.01366	0.01429	0.00857
1980.4	250.94855	0.92008	0.01459	0.01058	0.01390
1981.1	250.62894	0.91880	0.01411	0.01095	0.04612
1981.2	258.44755	0.94952	0.01356	0.00974	0.01464
1981.3	254.46962	0.93401	0.01439	0.00997	0.01054
1981.4	253.53635	0.93034	0.01641	0.01357	0.01396
1982.1	249.56165	0.91454	0.01574	0.01485	0.01277
1982.2	250.85165	0.91969	0.01599	0.01463	0.01241
1982.3	261.28814	0.96045	0.01561	0.01423	0.01279
1982.4	263.55602	0.96910	0.01683	0.01505	0.01642
1983.1	263.65197	0.96946	0.01398	0.01368	0.01267

1983.2	266.07254	0.97860	0.01364	0.00962	0.01263
1983.3	272.60442	1.00285	0.01546	0.01165	0.01413
1983.4	266.93604	0.98184	0.01630	0.01452	0.01631
1984.1	269.92928	0.99299	0.01499	0.01344	0.01159
1984.2	273.59743	1.00649	0.01544	0.01155	0.01165
1984.3	271.19501	0.99767	0.01549	0.01180	0.01373
1984.4	270.59208	0.99544	0.01638	0.01301	0.01495
1985.1	277.56929	1.02090	0.01504	0.01284	0.01193
1985.2	283.70953	1.04278	0.01478	0.01066	0.01209
1985.3	285.16979	1.04791	0.01477	0.00995	0.01193
1985.4	283.74824	1.04292	0.01568	0.01037	0.01377
1986.1	289.77596	1.06394	0.01609	0.01175	0.01255
1986.2	300.16397	1.09916	0.02060	0.01789	0.01772

Table 2C

Dallas Price Indexes and Standard Errors

Quarter	Index	B=log (Index/100)	SE(b)	$SE(b-b_{-1})$	$SE(b-b_{-4})$
1970.1	100.00000	0.00000	0.00000	0.00000	0.00000
1970.2	105.69492	0.05539	0.07275	0.07275	0.00000
1970.3	108.77367	0.08410	0.08049	0.08646	0.00000
1970.4	106.79829	0.06577	0.05366	0.07366	0.00000
1971.1	105.70844	0.05551	0.05759	0.04746	0.05759
1971.2	113.13130	0.12338	0.05231	0.04163	0.06105
1971.3	114.89652	0.13886	0.04924	0.02891	0.06661
1971.4	119.63193	0.17925	0.05106	0.02590	0.03934
1972.1	118.70577	0.17148	0.04884	0.02663	0.03748
1972.2	114.34642	0.13406	0.04852	0.02474	0.02887
1972.3	119.27030	0.17622	0.04911	0.02618	0.02491
1972.4	127.10105	0.23981	0.05169	0.02947	0.02967
1973.1	122.89447	0.20616	0.04923	0.02613	0.02292
1973.2	127.62621	0.24394	0.04869	0.02033	0.02268
1973.3	132.48609	0.28131	0.04881	0.01905	0.02378
1973.4	126.24838	0.23308	0.05019	0.02306	0.02853
1974.1	131.45060	0.27346	0.04881	0.02152	0.02044
1974.2	135.60477	0.30457	0.04869	0.01818	0.01920
1974.3	136.78543	0.31324	0.04973	0.02034	0.02216
1974.4	138.18107	0.32339	0.05145	0.02656	0.02777
1975.1	139.19216	0.33069	0.05081	0.02715	0.02355
1975.2	146.28956	0.38042	0.04883	0.02387	0.01928
1975.3	147.32662	0.38748	0.04874	0.01917	0.02162
1975.4	149.48500	0.40203	0.04977	0.02179	0.02698
1976.1	142.33511	0.35301	0.04805	0.02026	0.02283
1976.2	149.55713	0.40251	0.04764	0.01398	0.01689
1976.3	153.40508	0.42791	0.04759	0.01259	0.01691
1976.4	154.99341	0.43821	0.04790	0.01312	0.01980
1977.1	159.80981	0.46881	0.04758	0.01290	0.01379
1977.2	168.87430	0.52398	0.04745	0.01114	0.01166
1977.3	174.84906	0.55875	0.04740	0.01035	0.01165
1977.4	183.38200	0.60640	0.04764	0.01101	0.01310
1978.1	190.19594	0.64288	0.04757	0.01174	0.01166
1978.2	202.37274	0.70494	0.04749	0.01132	0.01075
1978.3	211.12100	0.74726	0.04758	0.01139	0.01075
1978.4	224.36170	0.80809	0.04777	0.01216	0.01238
1979.1	241.01262	0.87968	0.04762	0.01241	0.01181
1979.2	246.85474	0.90363	0.04743	0.01073	0.01081
1979.3	260.07948	0.95582	0.04738	0.00976	0.01071
1979.4	262.48024	0.96501	0.04789	0.01187	0.01346
1980.1	277.64453	1.02117	0.04777	0.01285	0.01237
1980.2	288.99288	1.06123	0.04771	0.01210	0.01128
1980.3	298.45553	1.09345	0.04753	0.01122	0.01035
1980.4	307.14159	1.12214	0.04798	0.01221	0.01389
1981.1	312.43099	1.13921	0.04768	0.01269	0.01228
1981.2	314.85336	1.14694	0.04765	0.01111	0.01210
1981.3	318.37218	1.15805	0.04770	0.01137	0.01135
1981.4	323.11128	1.17283	0.04846	0.01451	0.01558
1982.1	332.53026	1.20156	0.04798	0.01518	0.01287
1982.2	337.21745	1.21556	0.04789	0.01339	0.01254
1982.3	341.05439	1.22687	0.04826	0.01417	0.01406

1982.4	344.50528	1.23694	0.04818	0.01505	0.01605
1983.1	353.81378	1.26360	0.04776	0.01330	0.01289
1983.2	362.27848	1.28724	0.04762	0.01124	0.01242
1983.3	370.96459	1.31094	0.04801	0.01229	0.01511
1983.4	368.17302	1.30338	0.04792	0.01328	0.01445
1984.1	380.62982	1.33666	0.04765	0.01189	0.01195
1984.2	387.06153	1.35341	0.04749	0.01047	0.01092
1984.3	393.70697	1.37044	0.04778	0.01087	0.01353
1984.4	396.64973	1.37788	0.04807	0.01303	0.01416
1985.1	404.91203	1.39850	0.04771	0.01267	0.01183
1985.2	406.09102	1.40141	0.04757	0.01029	0.01064
1985.3	410.25685	1.41161	0.04766	0.01091	0.01232
1985.4	408.91759	1.40834	0.04791	0.01182	0.01409
1986.1	419.55520	1.43402	0.04819	0.01399	0.01370
1986.2	409.25671	1.40917	0.05121	0.02225	0.02193

Table 2D

San Francisco Price Indexes and Standard Errors

Quarter	Index	B=log (Index/100)	SE(b)	$SE(b-b_{-1})$	$SE(b-b_{-4})$
1970.1	100.00000	0.00000	0.00000	0.00000	0.00000
1970.2	99.59789	-0.00403	0.02534	0.02534	0.00000
1970.3	98.48914	-0.01522	0.03430	0.03658	0.00000
1970.4	107.25969	0.07008	0.02109	0.03191	0.00000
1971.1	107.49470	0.07227	0.02115	0.01973	0.02115
1971.2	108.58855	0.08240	0.01926	0.01754	0.02317
1971.3	110.23296	0.09743	0.01915	0.01594	0.03235
1971.4	110.93322	0.10376	0.01881	0.01536	0.01730
1972.1	114.08595	0.13178	0.01890	0.01454	0.01716
1972.2	116.81113	0.15539	0.01829	0.01369	0.01455
1972.3	117.97229	0.16528	0.01783	0.01237	0.01379
1972.4	119.83982	0.18099	0.01818	0.01186	0.01323
1973.1	121.29570	0.19306	0.01766	0.01117	0.01262
1973.2	124.41727	0.21847	0.01784	0.01100	0.01233
1973.3	131.61747	0.27473	0.01830	0.01214	0.01225
1973.4	133.42452	0.28837	0.01822	0.01274	0.01236
1974.1	137.04970	0.31517	0.01761	0.01175	0.01050
1974.2	141.12111	0.34445	0.01782	0.01094	0.01133
1974.3	145.13912	0.37252	0.01808	0.01134	0.01218
1974.4	149.37452	0.40129	0.01868	0.01255	0.01286
1975.1	153.83681	0.43072	0.01758	0.01189	0.01054
1975.2	157.73627	0.45575	0.01711	0.00931	0.00976
1975.3	163.44656	0.49132	0.01730	0.00875	0.01044
1975.4	168.00753	0.51884	0.01739	0.00914	0.01159
1976.1	174.65586	0.55765	0.01697	0.00858	0.00922
1976.2	183.75744	0.60845	0.01682	0.00746	0.00773
1976.3	192.65927	0.65575	0.01686	0.00704	0.00810
1976.4	201.24346	0.69935	0.01706	0.00759	0.00861
1977.1	220.63956	0.79136	0.01682	0.00739	0.00718
1977.2	241.48942	0.88166	0.01689	0.00697	0.00699
1977.3	256.75702	0.94296	0.01717	0.00783	0.00763
1977.4	259.78206	0.95467	0.01716	0.00851	0.00814
1978.1	269.93000	0.99299	0.01709	0.00811	0.00728
1978.2	281.59159	1.03529	0.01707	0.00792	0.00741
1978.3	285.60483	1.04944	0.01707	0.00785	0.00809
1978.4	299.03165	1.09538	0.01810	0.00996	0.01015
1979.1	296.30217	1.08621	0.03009	0.02673	0.02606
1979.2	328.87059	1.19049	0.06620	0.06907	0.06428
1979.3	347.17189	1.24465	0.04983	0.07966	0.04747
1979.4	356.18127	1.27027	0.04261	0.06136	0.04026
1980.1	382.32569	1.34110	0.03228	0.04816	0.03775
1980.2	395.54818	1.37510	0.02252	0.03191	0.06608
1980.3	410.31704	1.41176	0.01844	0.01733	0.04760
1980.4	421.48909	1.43862	0.01984	0.01344	0.04008
1981.1	441.51454	1.48504	0.01933	0.01459	0.02971
1981.2	448.04930	1.49973	0.01956	0.01343	0.01884
1981.3	443.31617	1.48911	0.02095	0.01570	0.01563
1981.4	430.37497	1.45949	0.02373	0.01985	0.02038
1982.1	437.16711	1.47515	0.02318	0.02313	0.01935
1982.2	457.43035	1.52045	0.02240	0.02083	0.01868
1982.3	438.87852	1.47905	0.02296	0.02026	0.02028
1982.4	439.81207	1.48118	0.02453	0.02236	0.02471
1983.1	442.47528	1.48721	0.02332	0.02357	0.02305

1983.2	457.25284	1.52007	0.02066	0.01872	0.01979
1983.3	457.86745	1.52141	0.01940	0.01423	0.01906
1983.4	460.07910	1.52623	0.01887	0.01133	0.02046
1984.1	469.38518	1.54625	0.01849	0.01076	0.01850
1984.2	474.54834	1.55719	0.01837	0.00935	0.01480
1984.3	478.12891	1.56471	0.01876	0.00972	0.01338
1984.4	481.12563	1.57096	0.01935	0.00977	0.01335
1985.1	493.63345	1.59662	0.01989	0.01188	0.01358
1985.2	508.73864	1.62676	0.02100	0.01651	0.01525
1985.3	526.01499	1.66016	0.02100	0.01728	0.01572
1985.4	521.42208	1.65139	0.02204	0.01795	0.01776
1986.1	539.62541	1.68571	0.02167	0.02029	0.01776
1986.2	569.61391	1.73979	0.02306	0.02065	0.02051
1986.3	555.58101	1.71484	0.03034	0.03034	0.02872

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 indices are estimates of the true housing prices, and as such there is noise in the estimates (due to the Δh and N terms in equation 1 above). 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 sales of the houses that are used to make up the index.[1]

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1. Of course, since our data is in effect quarterly averaged, we expect a serial correlation coefficient (and coefficient of the lagged value in the kind of autoregressions described below) of 0.25.

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 -.351 for Atlanta, +.240 for Chicago, -.0200 for Dallas, and +.174 for San Francisco. The 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% level). The coefficient of the lagged quarter-to-quarter change in the regression with seasonal dummies is -.351, +.346, -.028, and +.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 $P-P_{-4}$ 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 WRS index we have constructed as very useful for the testing of market efficiency. In our companion paper (Case and Shiller [1987], 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 WRS index up to that quarter.