

Improved Price Indexes for Real Estate: Measuring the Course of Swedish Housing Prices*

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This paper presents an improved methodology for estimating asset prices for real estate and other durables. The method is used to analyze house price dynamics by exploiting an unusually rich and detailed body of data—extensive descriptive and financial information on every house sale in Sweden during a 12-year period.

The results confirm the importance of many aspects of quality in affecting the course of housing prices, as well as the role of individual-specific and idiosyncratic aspects of housing. The results are compared with the price trends produced by more primitive methods and published by official sources. © 1998 Academic Press

I. INTRODUCTION

The imputation of market prices for land, office buildings, apartments, and other forms of real estate is a complex undertaking. Real estate varies widely in “quality” and trades are infrequent, rendering standard methods

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for computing price indexes inadequate. Research designed to estimate the course of prices has intensified over the last several years. While there are other durable goods that have also been the subject of study, most of the attention has been directed to housing. This is hardly surprising. Housing, which represents more than 50% of the U.S. private capital stock and 30% of household expenditures, is a conspicuous example of a nonstandard and seldom-traded good, one whose aggregate price movements are of great practical interest to policy makers and consumers as well as to academics.

The accurate measurement of housing and real estate price trends is itself crucial to understanding market behavior. For example, recent conclusions about the "efficiency" of the housing market depend crucially upon specific techniques which generate the price indexes used to measure the returns to arbitrage [6]. Similarly, models which investigate the determinants of speculative bubbles in real estate [1] rely upon index number techniques for the measurement of prices.

Finally, accuracy in measurement of housing prices is of enormous practical importance. Applications range from the estimation of regional variation in the cost of living to the computation of transfer payments under housing subsidy programs. As primary housing markets have become more integrated with secondary markets, the computation of housing prices has become of great practical importance to investors who confront choices among portfolios composed of real estate securities and other assets [17].

This paper presents an improved methodology for estimating asset prices for durables such as residential housing. (The original work on this topic appeared more than three decades ago; see Bailey, Muth, and Nourse [2]. The method extends and synthesizes several techniques recently suggested [4, 11] for combining so-called hedonic and repeat-sales methods used in the construction of housing price indexes. The methods we introduce apply equally well to other durables.

The improved model is used to compute price indexes for owner-occupied homes in Sweden, relying upon the most detailed and complete body of housing market information ever assembled. The data consist of essentially all used owner-occupied dwellings sold at arms length in Sweden during the period 1981–1993. Individual house sales are recorded nationally by the Central Bureau of Statistics, together with extensive information on the characteristics of dwellings, structures, and parcels. Our analysis makes use of the master file of sales information, containing observations on over 500,000 owner-occupied property sales between January 1, 1981 and August 28, 1993.

Section II describes the statistical model, a synthesis of several "hybrid models" proposed in the literature. Section III describes the data on

housing prices and the salient features of the Swedish housing market. Section IV presents and interprets our results, and Section V offers some concluding comments comparing our index with that published by the Central Bureau of Statistics.

II. THE STATISTICAL MODEL

By now, the general properties of hedonic and repeat-sales models of housing price indexes are well known, and the advantages of "hybrid" techniques combining the two approaches are well established (see [4, 5, 11, 16]). In this section, we introduce an estimation technique combining the desirable features of several estimators currently used. The model we develop is intended to make full use of a data set rich in information about dwelling characteristics and in which repeat sales are identified. The model utilizes multiple sales of the same house to estimate the error structure of the price-generating process. This supports generalized least squares estimation of a hedonic regression which uses all observed housing sales, potentially improving the efficiency of all parameter estimates.

Assume that the sale price of a housing unit is an amalgam, PQ , of an index representing the price, P , of a housing unit and another index representing the level of services, Q , emitted by that unit. To represent this, suppose

$$V_{it} = Q_{it} + P_t + \omega_{it}, \quad (1)$$

where V_{it} is the logarithm of the observed selling price of house i at time t , Q_{it} is the log of the quality of house i sold at time t , and P_t is the log of the constant quality housing price index at time t . ω_{it} is a random error, reflecting idiosyncratic aspects of particular transactions, e.g., a "distressed" sale.

According to (1), each house emits a quality of service Q_{it} which is priced at P_t at a particular point in time. Q_{it} is unobserved, but

$$Q_{it} = \beta X_{it} + \xi_i + \eta_{it}. \quad (2)$$

According to (2), housing quality is a function of a vector of observable characteristics of dwellings at time t , X_{it} , a dwelling-unit-specific factor, ξ_i , and a random error, η_{it} . The vector X_{it} may include the vintage (production year) of the dwelling as well as the accumulated physical depreciation of that dwelling at year t . The term ξ_i represents the unmeasured characteristics of house i . Combining (1) and (2) yields

$$\begin{aligned} V_{it} &= \beta X_{it} + P_t + \delta_{it} \\ &= \beta X_{it} + P_t + \xi_i + \varepsilon_{it}, \end{aligned} \quad (3)$$

where ε_{it} is a composite error term,

$$\varepsilon_{it} = \eta_{it} + \omega_{it}. \quad (4)$$

Assume

$$E(\xi_i) = 0, \quad E(\xi_i)^2 = \sigma_\xi^2. \quad (5)$$

If all dwellings in a given sample were repeat sales, all the parameters of the model could be estimated by making further assumptions about the structure of the errors, ε_{it} . In the analysis below, we assume these errors, ε_{it} , are generated by a first-order autoregressive process.¹

Multiple observations on dwellings, i.e., repeat sales, provide three sources of information in estimating the model:

First, they permit the systematic components of housing quality to be distinguished from the unmeasured idiosyncratic components, ξ_i , that vary among individual dwelling units.

Second, they permit the depreciation of dwellings to be distinguished from the vintage of dwellings. Presumably, newer dwellings embody technical progress which makes them more valuable. However, for a given construction vintage, sales observed later in time should be at lower prices, *ceteris paribus*, reflecting physical depreciation of the asset.

Third, multiple sales permit an explicit analysis of the error generating process, which potentially improves the efficiency of estimation of the price index P_t , as well as the parameters β .

A sample of single sales permits (3) to be estimated, but it does not permit the measured characteristics of houses to be distinguished from the unmeasured, individual-specific characteristics of those dwelling units. Presumably, many characteristics of individual houses that are difficult to measure quantitatively, particularly in a large sample, are important in affecting house values. Similarly, in a single cross section, depreciation cannot be distinguished from the effects of vintage and the course of pure price change over real time. In a linear model, the variables are simply colinear. Finally, single sales do not permit any investigation of the autocorrelated structure of errors.

To combine samples of single and multiple sales in the same analysis, combine (3) and (4):

$$\begin{aligned} V_{it} &= \beta X_{it} + P_t + \xi_i + \varepsilon_{it} \\ &= \beta^* X_{it}^* + \beta_y YR_i + \beta_d AGE_{it} + \sum_{j=0}^s \phi_j D_j + \xi_i + \varepsilon_{it}. \end{aligned} \quad (6)$$

¹Much related work assumes these errors are generated by a random walk. However, recent empirical research rejects a random walk in favor of an autocorrelated error structure by a wide margin. See Hill *et al.* [12].

V_{it} , X_{it} , P_t , ξ_i , and ε_{it} are defined as above. In the second line, two components of the vector of housing characteristics have been expressed separately, leaving the remaining vector X_{it}^* and the coefficient vector β^* . The housing characteristics represented separately include the year the dwelling was built (YR_i) and the depreciation of the dwelling (AGE_{it} , the age of the dwelling at year t). The combined effect of the year built on housing prices is $\beta_y YR_i$, and the accumulated effects of depreciation are $\beta_d AGE_{it}$, where β_y and β_d are estimated coefficients. The separate effect of the vintage of construction, β_v , on housing prices is simply $(\beta_y - \beta_d)$.

The price level at any period t is parameterized by a set of variables D_t which take on a value of 1 for all time periods prior to the observed sale and 0 for all periods after the observed sale,² i.e.,

$$P_t = \sum_{j=0}^s \phi_j. \quad (7)$$

Obviously, the parameters of (6) cannot be estimated directly, since vintage, age, and time of sale are colinear. Using the subsample of repeat sales alone, however, we can estimate

$$V_{it} = \beta^* X_{it}^* + \beta_y YR_i + \sum_{j=0}^s \phi_j D_j + \gamma_{it}, \quad (8)$$

where

$$\gamma_{it} = \beta_d AGE_{it} + \xi_i + \varepsilon_{it}. \quad (9)$$

The residuals from (8) are sufficient to provide an estimate of the depreciation parameter β_d and the error structure of ε_{it} :

$$\gamma_{it} - \gamma_{i\tau} = \beta_d(t - \tau) + \varepsilon_{it} - \varepsilon_{i\tau}, \quad (10)$$

$$\varepsilon_{it} = \rho^{t-\tau} \varepsilon_{i,t-\tau} + v_{it}, \quad (11)$$

assuming that v_{it} is white noise.

The error variances, σ_ξ^2 and σ_v^2 , are estimated from (8) and (11). The depreciation coefficient is estimated from (10).

²In the empirical analysis reported below, the price index is estimated quarterly beginning with 1981:I. However, the exact sale date is recorded and the elapsed time since January 1, 1981 is used to define the set of time intervals, D . For example, for a house sold on December 31, 1981, the values are $D_1 = D_2 = D_3 = D_4 = 1$, and 0 thereafter. For a house sold on February 15, 1982, the values are $D_1 = D_2 = D_3 = D_4 = 1$, $D_5 = 0.5$, and 0 thereafter.

Together, these parameters identify completely the variance-covariance matrix of disturbances in (6):

$$E(\gamma_{it}\gamma_{i\tau}) = \begin{cases} 0, & \text{for } i \neq j, \\ \sigma_{\xi}^2 + \sigma_v^2\{\rho^{(t-\tau)}/(1-\rho^2)\} + \beta_d^2\text{AGE}_t\text{AGE}_\tau, & \text{for } i = j. \end{cases} \quad (12)$$

Now, using the entire sample of single sales and repeat sales, estimate (8) by generalized least squares (GLS), where the GLS matrix is the inverse of the right-hand side of (12).

This approach, which uses all sales observations, not just repeat sales, in a common framework, is an extension of the hybrid techniques proposed by Quigley [16] and by Hill, Knight, and Sirmans [11] (HKS). Each of these previous models relies upon an explicit error structure to combine single sales and multiple sales in a common regression framework. In common with the HKS model, the estimator proposed here distinguishes between vintage and depreciation in their effects upon housing prices. In contrast to the HKS model, the estimator proposed here distinguishes between the individual-specific components of house values and random errors. Presumably, characteristics of dwellings that remain unmeasured by hedonic surveys are important in price determination. The model developed here recognizes this.

This proposed technique is also simple to implement—relying upon generalized least squares models rather than maximum likelihood methods. In contrast to the model proposed by Quigley, the estimator proposed here incorporates a conventional autoregressive structure rather than the more cumbersome assumption of a random walk in housing prices.³

In contrast to conventional repeat-sales methods, which have been routinely applied to the art market as well as the housing market, the estimator proposed here is based upon all market information, not just that provided by multiple sales of the same property.

Thus, efficiency gains come from two sources: first, the estimation of an explicit error structure which leads to generalized least squares estimators; second, the use of information on all house sales, not merely repeat sales.

Finally, it should be noted that the price index, I_t , specified by (7),

$$I_t = \exp(P_t) = \exp\left(\sum_{j=0}^t \phi_j\right), \quad (13)$$

³The recent empirical analysis reported by Hill, Knight, and Sirmans [11] provides convincing evidence that the simple model of serial correlation “fits the data” as well as the random walk model, at least in one empirical application.

is measured relative to a particular set of housing characteristics in a given year. Absolute comparisons of prices can be made across markets, as well as time periods, for different configurations of housing attributes. These comparisons cannot be made for repeat sales indexes.

III. THE DATA

Housing transactions data are recorded routinely in Sweden and are maintained historically by the Central Bureau of Statistics (SCB) in Stockholm. The raw data utilized in this study consist of all residential (non-farm) housing sales recorded during the 1981:I–1993:III period divided into eight geographical regions.⁴ These regions were defined by SCB for administrative purposes. We maintain these distinctions to facilitate comparisons between our indexes and those produced by SCB.

Sales prices are taken directly from the sales contract that is submitted to court in order to obtain legal confirmation of ownership. Information about characteristics derive from forms submitted by the homeowner to the tax authorities, information that is used to assess values for property tax purposes.

Figure 1 shows the regional breakdown of the data. The eight regions vary in geographical size between the capital region of Stockholm (region I) and the rural north (region VIII). Table I reports the distribution of dwellings by the number of sales during the 12-year period in each region. About three-quarters of the dwellings in the sample were sold once, but the distribution of sales has a long tail within each region. The analysis sample consists of 533,894 transactions⁵ on 423,963 houses.

⁴The raw data are maintained on two separate files: one (370,860 observations) containing all multiple house sales (the “repeat-sales” file) during the period and another (692,456 observations) containing all arms-length housing sales in the country during the same period (the “all-sales” file). The former file includes a unique identification number for each different property; the latter file does not include any identifying information at all. Both files have the same format and contain a large number of variables measuring property characteristics. In the first step of the analysis, the two files were merged. Then, those observations in the “all-sales” file whose characteristics matched exactly those of an observation in the “repeat-sales” file were eliminated (an exact match was sought on sale date and minor civil division as well as a variety of physical characteristics of the properties). We also eliminated duplicate records, again using exact matches. We also deleted multiple sales within a half year of each other. In this way redundant records were eliminated from the merged file. Because the data identify repeat sales and describe the attributes of dwellings, we can, in principle, explore the maintained hypothesis of the most widely used repeat-sales models [6]: that the use of multiple sales controls adequately for quality differences. This work is currently underway.

⁵From the original all-sales file we have deleted all transactions involving institutions as buyer or seller, and a number of cases with missing observations on one or more of the housing characteristics. We have also excluded properties with very large lot sizes (above 10,000 square meters).

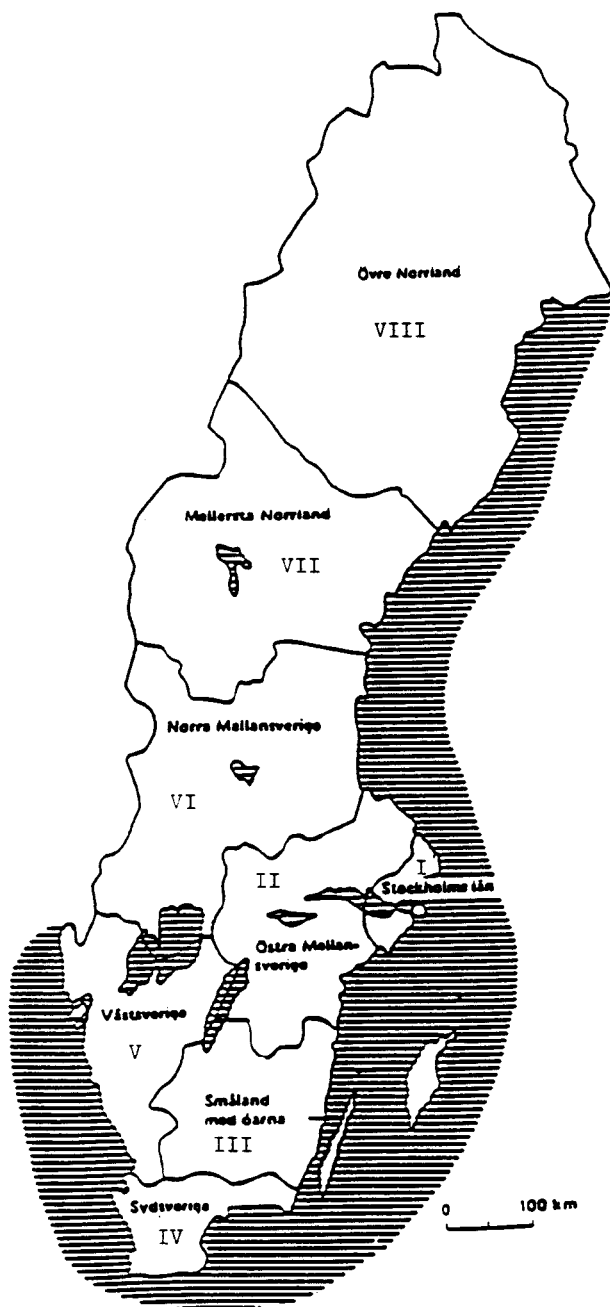


FIG. 1. Boundaries of major economic regions in Sweden. Source: Central Bureau of Statistics.

TABLE I
Number of Dwellings and Sales, 1981:I-1993:III

Number of sales	Region								Total number of dwellings	Total number of transactions
	I	II	III	IV	V	VI	VII	VIII		
1	47,100	59,170	34,013	54,806	67,014	38,440	14,455	19,009	334,007	334,007
2	10,083	12,867	7,192	12,858	14,429	7,793	3,139	4,439	72,800	145,600
3	1,829	2,704	1,418	2,759	2,798	1,638	682	920	14,748	44,244
4	273	364	195	397	404	196	98	136	2,063	8,252
5	40	66	18	67	48	17	17	23	296	1,480
6	3	14	1	2	3	2	3	6	34	204
7	2	7	0	1	1	0	1	1	13	91
8	0	1	0	0	0	0	1	0	2	16
Total	59,330	75,193	42,837	70,890	84,697	48,086	18,396	24,534	423,963	533,894

Table II summarizes the average characteristics of houses sold in the eight regions during this period. As indicated in Table II, the average selling price of houses in Stockholm, 772,655 SEK (or roughly \$100,000 U.S.) was more than 55% larger than the average in the other regions. The average interior size, about 120 square meters, was quite similar across regions, while the average lot size was much smaller in Stockholm, 827 square meters, than in the other seven regions, which averaged 1100–1400 square meters.

The raw data include a wide variety of indicators of the quality and amenity of dwellings. On the basis of preliminary analyses, we have included a number of these in the determination of price. Included are two size variables and dummy variables for the number of garages; nine dummy variables recording various amenities, including, for example, the existence of an open fireplace, a sauna, a laundry room; and 12 dummy variables measuring the quality of insulation, heating systems, kitchens, and roofs. In addition, we record the vintage (year of construction) of each dwelling and its age at sale.

Each dwelling is located in one of 111 well-defined labor market areas. Region I is a single labor market area (Stockholm); other regions are composed of several labor market areas (up to 24 areas for region VI). For each dwelling, we measure the straight line distance to the economic center of its labor market area.⁶

In addition to these qualitative and quantitative aspects of the dwellings, we measure and hold constant one potentially important financial aspect of these house sales, namely, the existence of transferable capital subsidies. Beginning in 1975, the Swedish government provided loans with guaranteed interest rates to the purchasers of newly constructed dwellings. The rules governing these subsidies varied over time, i.e., with year of construction. They also varied with the size and construction cost of dwellings. Because the subsidy is tied to a specific dwelling, in the event of sale it is potentially capitalized into the selling price for a used house. We include an estimate of the present value of the remaining subsidy at the time of sale as a variable in the analysis.⁷

⁶More precisely, we measure the straight line distance of the parish containing each dwelling to the center of its economic area. Parishes are roughly the size of U.S. census tracts and are subject to the same ambiguities in measuring distances from their centroids, i.e., urban parishes are usually smaller in geographical area than rural parishes.

⁷The present value of these capital subsidies depends upon the difference between the market interest and the guaranteed interest rate over the period of the guarantee. Because these subsidies interact with the tax code, their value also depends upon the marginal tax rate of the owner. The assumptions underlying the computation of the particular present value estimates we use are discussed in Berger *et al.* [3].

As indicated in Table II, the present value of the average subsidy for all transactions in this sample is small, about 3000 SEK or \$400 U.S. However, for those transactions which include a subsidized house, the average value of the remaining capital subsidy is as high as 26,000 SEK or \$3300 U.S. The average conditional subsidy is thus between 3 and 6% of the average sale price.

IV. RESULTS

Table III presents estimates of (6) based upon the subset of dwellings sold more than once. This regression of the logarithm of selling price upon housing characteristics is estimated by ordinary least squares. The general specification of the regression equation is identical for all eight regions.

Table IV presents the GLS estimates of the parameters of (6) as well as the estimates of (10) and (11). Panel A reports the GLS coefficients using the variance-covariance matrix reported in (12).

The coefficient of almost every variable reported in panel A is precisely estimated and is plausible in magnitude. The elasticity of housing value with respect to interior size is about 0.5; with respect to parcel area, it is about 0.3 at the means. Of the 72 dummy variables indicating amenities, all have the anticipated sign. Of these measures of amenity, 69 are significant by conventional criteria. Saunas and fireplaces increase housing values, as do waterfront locations (especially in Stockholm, but less so in the cold north!).

Almost all of the 96 dummy variables indicating quality—insulation, heating systems, etc.—are significant and economically important. In particular, houses with high quality kitchens and heating systems are much more valuable than others.

As expected, the distance to the employment center is highly significant. The price gradient for the monocentric region, Stockholm, indicates a relative price reduction of 0.8% per kilometer from the city center.⁸

Almost all of the price gradients for the 110 other labor market areas (not shown) are negative, significant, and of the same order of magnitude as the gradient for Stockholm.

The coefficient on the subsidy variable is highly significant, with coefficients varying between 2.25 and 3.43. These coefficients imply that a substantial majority of the benefits afforded during this period to purchasers of new homes was capitalized and “sold” to subsequent buyers of

⁸This form of the distance-price relationship, an exponential decline, is a standard result in urban location theory. See Muth [15].

TABLE II
Average Characteristics of House Sales by Region, 1981:I-1993:III (Standard Deviations in Parentheses)

	Region							
	I	II	III	IV	V	VI	VII	VIII
Sale Price (Crowns, SEK)	772.655 (462.05)	475.247 (239.55)	377.633 (202.20)	438.664 (283.62)	496.385 (346.02)	384.025 (195.01)	378.873 (208.20)	404.514 (214.35)
Size								
Interior size (square meters)	122.004 (35.98)	119.483 (36.38)	122.416 (39.70)	119.678 (39.88)	118.256 (37.78)	116.335 (37.72)	116.514 (37.66)	117.777 (35.65)
Parcel size (square meters)	827.392 (814.00)	1138.848 (1138.62)	1292.384 (1139.64)	1084.492 (1080.94)	1092.914 (1109.95)	1357.871 (1208.83)	1372.589 (1236.33)	1202.663 (1101.09)
One car garage (1 = yes)	0.705 (0.46)	0.706 (0.46)	0.653 (0.48)	0.581 (0.49)	0.621 (0.49)	0.641 (0.48)	0.641 (0.48)	0.726 (0.45)
Two car garage (1 = yes)	0.047 (0.21)	0.078 (0.27)	0.069 (0.25)	0.044 (0.20)	0.059 (0.24)	0.073 (0.26)	0.056 (0.23)	0.101 (0.30)
Amenity								
Tile bath (1 = yes)	0.118 (0.32)	0.091 (0.29)	0.095 (0.29)	0.143 (0.35)	0.110 (0.31)	0.081 (0.27)	0.074 (0.26)	0.068 (0.25)
Sewer connection (1 = yes)	0.988 (0.11)	0.984 (0.13)	0.979 (0.14)	0.974 (0.16)	0.977 (0.15)	0.984 (0.12)	0.990 (0.10)	0.993 (0.08)
sauna (1 = yes)	0.217 (0.41)	0.216 (0.41)	0.177 (0.38)	0.122 (0.33)	0.177 (0.38)	0.188 (0.39)	0.206 (0.40)	0.388 (0.49)
Stone/brick (1 = yes)	0.234 (0.42)	0.353 (0.48)	0.346 (0.48)	0.548 (0.50)	0.288 (0.45)	0.243 (0.43)	0.164 (0.37)	0.190 (0.39)
Single detached (1 = yes)	0.664 (0.47)	0.807 (0.39)	0.877 (0.33)	0.865 (0.34)	0.784 (0.41)	0.881 (0.32)	0.852 (0.36)	0.866 (0.34)
Finished basement (1 = yes)	0.162 (0.37)	0.185 (0.39)	0.199 (0.40)	0.134 (0.34)	0.171 (0.38)	0.158 (0.37)	0.173 (0.38)	0.162 (0.37)
Fireplace (1 = yes)	0.368 (0.48)	0.342 (0.47)	0.468 (0.50)	0.259 (0.44)	0.339 (0.47)	0.379 (0.49)	0.345 (0.48)	0.287 (0.45)

Laundry room (1 = yes)	0.842 (0.36)	0.817 (0.39)	0.791 (0.41)	0.784 (0.41)	0.811 (0.39)	0.747 (0.43)	0.755 (0.43)	0.824 (0.38)
Waterfront location (1 = yes)	0.007 (0.08)	0.005 (0.07)	0.007 (0.08)	0.004 (0.07)	0.004 (0.06)	0.012 (0.11)	0.014 (0.12)	0.012 (0.11)
Quality								
Age at time of sale (Years)	26.572 (20.48)	30.738 (24.75)	35.400 (26.38)	39.674 (28.42)	30.578 (23.46)	33.935 (24.87)	34.435 (25.03)	30.166 (24.39)
Vintage (19xx)	59.915 (20.35)	55.705 (24.63)	51.343 (26.29)	47.057 (28.33)	55.995 (23.33)	52.745 (24.72)	52.293 (24.94)	56.624 (24.38)
Insulation								
Walls only (1 = yes)	0.832 (0.37)	0.802 (0.40)	0.809 (0.39)	0.802 (0.40)	0.791 (0.41)	0.803 (0.40)	0.783 (0.41)	0.708 (0.45)
Walls and windows (1 = yes)	0.163 (0.37)	0.191 (0.39)	0.172 (0.38)	0.179 (0.38)	0.195 (0.40)	0.190 (0.39)	0.211 (0.41)	0.288 (0.45)
Kitchen								
Good (1 = yes)	0.198 (0.40)	0.217 (0.41)	0.257 (0.44)	0.279 (0.45)	0.247 (0.43)	0.294 (0.46)	0.267 (0.44)	0.217 (0.41)
Excellent (1 = yes)	0.789 (0.41)	0.760 (0.43)	0.703 (0.46)	0.687 (0.45)	0.725 (0.45)	0.668 (0.47)	0.692 (0.46)	0.762 (0.43)
Heating system								
Electric radiator (1 = yes)	0.400 (0.49)	0.322 (0.47)	0.313 (0.46)	0.323 (0.47)	0.359 (0.48)	0.304 (0.46)	0.369 (0.48)	0.374 (0.48)
Electric furnace (1 = yes)	0.111 (0.31)	0.086 (0.28)	0.075 (0.26)	0.090 (0.29)	0.106 (0.31)	0.098 (0.30)	0.105 (0.31)	0.177 (0.38)
Solar/other (1 = yes)	0.344 (0.48)	0.367 (0.48)	0.501 (0.50)	0.478 (0.50)	0.424 (0.49)	0.486 (0.50)	0.445 (0.50)	0.364 (0.48)
Exterior steam (1 = yes)	0.083 (0.28)	0.176 (0.38)	0.048 (0.21)	0.067 (0.25)	0.037 (0.19)	0.056 (0.23)	0.023 (0.15)	0.049 (0.21)
Other central heat (1 = yes)	0.050 (0.22)	0.021 (0.14)	0.022 (0.15)	0.021 (0.14)	0.051 (0.22)	0.020 (0.14)	0.024 (0.15)	0.009 (0.09)
Wood burning stove (1 = yes)	0.009 (0.09)	0.021 (0.14)	0.027 (0.16)	0.009 (0.09)	0.018 (0.13)	0.026 (0.16)	0.024 (0.15)	0.025 (0.16)

TABLE II—Continued

	Region							
	I	II	III	IV	V	VI	VII	VIII
Roof								
Cement/steel (1 = yes)	0.663 (0.47)	0.768 (0.42)	0.806 (0.40)	0.657 (0.47)	0.766 (0.42)	0.768 (0.42)	0.596 (0.49)	0.466 (0.50)
Slate/copper (1 = yes)	0.009 (0.10)	0.009 (0.09)	0.011 (0.10)	0.015 (0.12)	0.013 (0.11)	0.010 (0.10)	0.008 (0.09)	0.007 (0.09)
Other								
Distance to center (Kilometers)	4.744 (6.09)	5.685 (6.84)	7.926 (9.44)	5.318 (5.30)	5.863 (5.81)	5.670 (8.78)	11.162 (14.11)	6.688 (13.40)
Urban area (1 = yes)	0.903 (0.30)	0.791 (0.41)	0.777 (0.42)	0.757 (0.43)	0.745 (0.44)	0.786 (0.41)	0.731 (0.44)	0.757 (0.43)
Capital subsidy (SEK)	2.979 (12.16)	2.847 (11.14)	2.525 (10.96)	2.361 (10.85)	2.845 (11.64)	2.597 (10.74)	2.532 (10.82)	2.789 (12.66)
Conditional subsidy (SEK)	25.863 (26.30)	22.501 (23.20)	23.064 (24.96)	24.769 (26.08)	24.013 (25.21)	20.996 (23.37)	22.554 (24.32)	21.913 (28.99)
Number of transactions	74077	94943	53527	90741	106147	59821	23289	31349
Number of dwellings	59330	75193	42837	70890	84697	48086	18396	24534

houses. At the means, capitalization of the average subsidy ranged from 55% in the far north (where population has been declining) to 130% in region II, the area surrounding Stockholm (where population has been increasing). Despite the large sample and the precisely estimated coefficients, we have little confidence in the precision of the estimated capitalization rates.⁹

Panel B of the table reports the estimate of depreciation and the autocorrelation coefficient, based upon analysis of the residuals from the OLS model. The estimate of the depreciation rate is small. Ten-year old houses depreciate by about 0.2%–0.9% per year during the rest of their lives. Of course, these statistical models hold at constant quality a host of economically important amenities and features—many of which typically vary substantially with the age of dwellings. The unmeasured factors, however, include the effects of wear and tear and landscaping, presumably age-related.

The coefficient of autocorrelation is negative and is precisely estimated in five of the eight regions.¹⁰ The magnitude, as large as -0.6 , suggests that autocorrelation is important for houses that are sold within two or three quarters after they were purchased, but it is not important at all for houses sold after intervals of, say, two years.¹¹ ($0.6^8 \cong 0.02$).

Given the high transactions costs in the housing market, a short interval between acquisition and disposition of a house reflects an unusual transaction. On the one hand, a rapid disposition may represent a “distressed sale” arising from divorce or job loss. Individuals forced to sell on short notice often take large losses. On the other hand, a rapid disposition may represent an unusual profit opportunity arising from an underpriced house by an uninformed seller. Either of these explanations is consistent with a

⁹Our lack of confidence in capitalization estimates arises from several sources. First, these subsidies were provided only to houses built after 1975. They are thus concentrated in new houses where depreciation is decidedly nonlinear. In the models reported in Table IV, we have included dummy variables for dwellings less than 10 years old. If these dummy variables are excluded (or if other plausible variants are adopted, say 5 or 15 dummy variables), there are minor differences in the estimated depreciation rate but larger changes in the estimated capitalization rate. We experimented by confining the sample to houses built after 1975. The estimate of capitalization is still sensitive to the specification of depreciation (age at sale). Beyond the correlation of capital subsidies with age, however, is the calculation of subsidy levels. This calculation is based on strong assumptions about discount rates and about expected future market interest rates. We conclude that capital subsidies are capitalized into the sale prices of used houses and that the specification employed is sufficient to hold constant these effects in the estimation of price indexes. We cannot say with confidence that the capitalization rate is 130% rather than 55%.

¹⁰The estimates of the autocorrelation parameter are obtained from equation (11) estimated by non-linear least squares using the samples of dwellings sold three or more times.

¹¹For dwellings sold more than once, the average elapsed time between sales is about five years.

TABLE III
 Estimates of (8) Based on all Multiple Sales—Dependent Variable: Logarithm of Selling Price

	Region							
	I	II	III	IV	V	VI	VII	VIII
Size								
Interior size (square meters)	0.496 (86.20)	0.500 (101.54)	0.531 (71.13)	0.590 (93.12)	0.494 (95.45)	0.518 (76.92)	0.506 (42.85)	0.531 (45.68)
Parcel size (square meters)	0.297 (9.72)	0.315 (9.92)	0.453 (7.95)	-0.075 (1.74)	0.334 (11.36)	0.101 (2.16)	0.324 (4.34)	0.222 (3.01)
Square of parcel size (square meters)	-0.021 (8.82)	-0.024 (9.76)	-0.038 (8.86)	0.004 (1.09)	-0.029 (12.28)	-0.008 (2.17)	-0.025 (4.42)	-0.022 (3.86)
One car garage (1 = yes)	-0.002 (0.69)	0.038 (10.77)	0.041 (8.00)	0.016 (4.05)	0.020 (5.92)	0.061 (13.26)	0.095 (11.96)	0.119 (13.19)
Two car garage (1 = yes)	0.084 (11.01)	0.081 (13.68)	0.095 (10.22)	0.051 (5.57)	0.088 (12.84)	0.105 (12.71)	0.144 (8.83)	0.155 (11.90)
Amenity								
Tile bath (1 = yes)	0.058 (12.29)	0.031 (6.61)	0.037 (5.24)	0.075 (14.78)	0.056 (11.96)	0.050 (7.31)	0.022 (1.79)	0.024 (1.98)
Sewer connection (1 = yes)	0.186 (11.64)	0.175 (14.61)	0.259 (14.04)	0.247 (18.67)	0.109 (10.42)	0.117 (6.38)	0.244 (6.32)	0.212 (4.90)
Sauna (1 = yes)	0.041 (10.68)	0.070 (19.79)	0.106 (18.21)	0.126 (21.60)	0.075 (18.20)	0.075 (14.43)	0.082 (9.28)	0.085 (12.14)
Stone/brick (1 = yes)	-0.001 (0.15)	0.035 (11.79)	0.058 (11.99)	0.059 (14.96)	0.044 (12.55)	0.042 (8.69)	0.050 (5.40)	0.073 (8.87)
Single detached (1 = yes)	0.080 (16.34)	0.057 (11.92)	0.074 (9.87)	0.002 (0.32)	0.053 (10.51)	0.103 (14.15)	0.045 (3.83)	0.042 (3.77)
Finished basement (1 = yes)	0.057 (13.23)	0.120 (30.89)	0.122 (20.49)	0.078 (13.39)	0.092 (21.83)	0.109 (18.97)	0.117 (12.52)	0.104 (11.52)
Fireplace (1 = yes)	0.108 (29.57)	0.066 (21.29)	0.045 (9.98)	0.112 (25.85)	0.079 (23.59)	0.072 (17.27)	0.047 (6.38)	0.084 (11.76)

Laundry room (1 = yes)	0.002 (0.41)	0.061 (15.24)	0.095 (15.28)	0.087 (17.17)	0.065 (15.41)	0.066 (12.80)	0.106 (11.62)	0.109 (11.92)
Waterfront location (1 = yes)	0.409 (18.11)	0.192 (9.56)	0.273 (9.86)	0.301 (9.71)	0.227 (8.89)	0.203 (10.44)	0.030 (1.00)	0.037 (1.23)
Quality								
Vintage (19xx)	-0.001 (10.85)	0.002 (26.70)	0.002 (21.31)	0.002 (25.72)	0.003 (30.59)	0.003 (30.82)	0.004 (21.30)	0.003 (16.82)
Insulation								
Walls only (1 = yes)	0.037 (1.49)	0.077 (4.63)	0.059 (3.57)	0.122 (8.85)	0.046 (3.60)	0.038 (1.70)	-0.049 (1.06)	-0.053 (0.99)
Walls and windows (1 = yes)	0.123 (4.90)	0.137 (7.98)	0.163 (9.25)	0.204 (13.83)	0.122 (9.15)	0.113 (4.89)	0.071 (1.51)	0.029 (0.53)
Kitchen								
Good (1 = yes)	0.102 (7.23)	0.113 (10.17)	0.083 (6.12)	0.033 (2.75)	0.103 (9.98)	0.079 (6.24)	0.136 (6.53)	0.133 (5.04)
Excellent (1 = yes)	0.128 (9.04)	0.193 (17.12)	0.201 (14.48)	0.153 (12.50)	0.184 (17.61)	0.179 (13.81)	0.263 (12.39)	0.269 (10.16)
Heating system								
Electric radiator (1 = yes)	0.059 (1.53)	0.185 (9.20)	0.215 (9.31)	0.199 (9.48)	0.309 (13.82)	0.207 (8.25)	0.353 (7.92)	0.268 (3.35)
Electric furnace (1 = yes)	0.090 (2.34)	0.250 (12.12)	0.276 (11.23)	0.294 (13.43)	0.369 (16.18)	0.212 (8.20)	0.400 (8.75)	0.321 (4.00)
Solar/other (1 = yes)	0.068 (1.77)	0.170 (8.42)	0.201 (8.62)	0.202 (9.58)	0.302 (13.44)	0.188 (7.46)	0.338 (7.57)	0.224 (2.80)
Exterior steam (1 = yes)	0.043 (1.11)	0.368 (17.90)	0.238 (9.45)	0.389 (17.43)	0.322 (13.69)	0.183 (6.92)	0.441 (8.96)	0.293 (3.61)
Other central heat (1 = yes)	0.092 (2.36)	0.228 (10.46)	0.298 (11.05)	0.266 (10.96)	0.293 (12.62)	0.216 (7.71)	0.419 (8.56)	0.258 (2.99)
Wood burning stove (1 = yes)	0.071 (1.72)	0.101 (4.63)	0.100 (3.87)	0.056 (1.99)	0.209 (8.54)	0.156 (5.75)	0.277 (5.58)	0.068 (0.84)
Roof								
Cement/steel (1 = yes)	0.102 (6.75)	0.021 (1.53)	-0.109 (5.50)	0.025 (1.71)	0.058 (4.56)	-0.010 (0.52)	0.041 (1.24)	-0.051 (1.58)

TABLE III—Continued

	Region							
	I	II	III	IV	V	VI	VII	VIII
Slate/copper (1 = yes)	0.054 (15.97)	0.014 (4.18)	0.013 (2.50)	0.035 (9.07)	0.035 (9.81)	-0.023 (4.91)	0.042 (5.91)	0.030 (4.18)
Other								
Distance to center ^c (Kilometers)	-0.008 (35.39)							
Urban area (1 = yes)	0.144 (25.41)	0.053 (13.18)	0.045 (7.24)	0.133 (27.65)	0.065 (16.07)	0.060 (10.76)	0.089 (10.11)	0.106 (13.02)
Capital subsidy (SEK)	2.117 (13.58)	3.443 (21.91)	3.801 (14.26)	3.297 (15.23)	3.539 (21.70)	4.598 (20.30)	2.467 (7.05)	3.822 (12.36)
Intercept	9.103 (88.34)	8.488 (82.39)	7.496 (39.58)	8.644 (61.19)	8.048 (82.55)	8.684 (55.08)	7.659 (30.33)	7.960 (31.64)
R^2	0.767	0.753	0.743	0.726	0.764	0.740	0.762	0.688
Number of transactions	26,977	35,773	19,514	35,935	39,133	21,381	8,834	12,340
Number of dwellings	12,230	16,023	8,824	16,084	17,683	9,646	3,941	5,525

Notes: t -ratios are in parentheses. Price index estimates, P_t , are not reported.

^aVariable measured in logarithms.

^bModel also includes two dummy variables, one indicating lot sizes between 2500 m² and 5000 m², the other indicating lot sizes of 5000 m² or more.

^cModel also includes separate intercepts and distance variables for each of 111 labor market areas. Region I, Stockholm, is considered a single labor market area.

large negative autocorrelation in prices for individual sales after short holding periods and essentially no autocorrelation in prices for individual sales after moderate or long holding periods.

Panel C reports the variance components and other parameters. The overall regression for each of the eight regions explains roughly three-fourths of the variation in housing prices. As indicated in panel C, about three-quarters of this residual variation represents unmeasured dwelling-specific effects. Only about 6% of the variation in housing prices is unrelated to housing attributes or the timing of sales. Also reported in panel C are the estimated capitalization rates (discussed above) and the estimated effect of vintage. According to the estimates, there is a small positive vintage effect—*ceteris paribus* new houses are more valuable. Again, many of the conventional aspects of vintage are measured explicitly in the data. The unmeasured vintage-related aspects of dwellings in this sample are probably quite subtle—the layout of rooms and stairways, for example.

V. DISCUSSION

Figures 2 and 3 summarize the price indexes derived from this analysis. They present the estimated selling price of a typical urban house (one with the average characteristics of houses sold in Stockholm) in each of the eight regions during the 1981–1993 period.¹² The course of housing prices throughout the country was roughly similar in different regions during the period—prices were flat in nominal terms through 1986, rose sharply through 1991, and were in free fall throughout the rest of the sample period. The figures reveal substantial regional deviations from this general trend. In particular, prices in the Stockholm region have been more volatile than prices in other regions. In 1981 the Stockholm price level was twice the price level in region III; at the peak in the first quarter of 1991 that ratio was 2.5 and in the second quarter of 1993 it was down to 2 again.

Explanations for the price development may be sought in fundamentals such as household disposable income and the tax and subsidy system [7, 13, 14]. Sweden entered the 1980s with towering budget deficits and switched to a more restrictive fiscal and monetary policy in 1981. Simultaneously, a tax reform, implemented gradually between 1982 and 1985, reduced the tax subsidies provided to owner-occupiers. After 1985, house prices started to rise again, partly driven by a more lax fiscal policy. A further stimulus to

¹² Note that we cannot really claim that the index represents the price level for the entire inventory of houses, but rather the price level for the stock of those sold. This is because the houses sold in any interval may be a nonrandom sample of the stock (see Gatzlaff and Haurin [9]). However, the long time interval used in this analysis (and the fact that about 40% of the stock appears in our sample) suggests that it may, indeed, be reasonable to impute this price index to the entire inventory.

TABLE IV
 Empirical Results from Generalized Least Squares: All Sales Parameters Affecting Housing Prices
 Estimates of (6), (10), and (11)—Dependent Variable: Logarithm of Selling Price

	Region							
	I	II	III	IV	V	VI	VII	VIII
Panel A. Results from GLS								
Size								
Interior size ^a (square meters)	0.516 (127.29)	0.512 (139.77)	0.528 (93.16)	0.610 (123.78)	0.514 (134.52)	0.513 (102.81)	0.547 (62.09)	0.574 (65.10)
Parcel size ^a (square meters)	0.310 (13.87)	0.349 (14.87)	0.187 (4.39)	0.073 (2.11)	0.284 (11.96)	0.043 (1.19)	0.422 (6.99)	0.421 (6.91)
Square of parcel size ^{a,b} (square meters)	-0.022 (12.16)	-0.026 (14.33)	-0.018 (5.63)	-0.006 (2.20)	-0.024 (13.05)	-0.002 (0.67)	-0.034 (7.28)	-0.039 (8.39)
One car garage (1 = yes)	-0.001 (0.42)	0.035 (13.86)	0.042 (11.78)	0.018 (6.81)	0.024 (10.25)	0.052 (16.43)	0.087 (15.33)	0.115 (17.97)
Two car garage (1 = yes)	0.067 (13.36)	0.098 (24.79)	0.095 (15.22)	0.049 (8.42)	0.085 (19.01)	0.108 (19.96)	0.131 (12.27)	0.140 (15.43)
Amenity								
Tile bath (1 = yes)	0.044 (15.22)	0.028 (9.97)	0.031 (7.48)	0.040 (13.80)	0.045 (15.95)	0.028 (7.06)	0.010 (1.25)	0.007 (0.95)
Sewer connection (1 = yes)	0.166 (16.88)	0.178 (21.40)	0.224 (18.29)	0.247 (27.63)	0.164 (23.59)	0.215 (17.46)	0.203 (8.27)	0.209 (7.74)
Sauna (1 = yes)	0.046 (18.07)	0.068 (29.16)	0.094 (24.09)	0.085 (23.79)	0.069 (24.97)	0.071 (21.42)	0.076 (12.78)	0.092 (18.26)
Stone/brick (1 = yes)	0.008 (3.45)	0.032 (15.38)	0.051 (15.44)	0.040 (14.99)	0.041 (16.69)	0.041 (13.15)	0.051 (7.83)	0.075 (12.19)
Single detached (1 = yes)	0.064 (21.99)	0.036 (13.51)	0.084 (20.25)	0.000 (0.06)	0.055 (18.31)	0.061 (15.10)	0.032 (4.47)	0.032 (4.48)
Finished basement (1 = yes)	0.056 (20.43)	0.108 (42.43)	0.113 (29.02)	0.069 (19.44)	0.074 (26.91)	0.095 (26.18)	0.093 (14.83)	0.088 (13.75)
Fireplace (1 = yes)	0.098 (39.88)	0.058 (27.51)	0.060 (19.23)	0.100 (34.33)	0.080 (34.79)	0.067 (23.80)	0.056 (10.74)	0.067 (13.20)

Laundry room	0.005	0.057	0.074	0.053	0.054	0.068	0.114	0.113
(1 = yes)	(1.78)	(22.19)	(18.94)	(17.27)	(20.41)	(20.69)	(19.22)	(18.86)
Waterfront location	0.325	0.230	0.217	0.180	0.164	0.141	0.075	0.040
(1 = yes)	(26.38)	(17.74)	(12.76)	(9.76)	(10.68)	(11.07)	(3.89)	(2.10)
Quality	-0.000	0.003	0.003	0.003	0.003	0.005	0.005	0.003
Vintage	(2.83)	(46.31)	(38.85)	(47.23)	(47.57)	(52.44)	(33.74)	(27.27)
Insulation								
Walls only	0.071	0.044	0.078	0.051	0.023	0.035	0.061	0.042
(1 = yes)	(5.14)	(3.88)	(7.29)	(5.67)	(2.92)	(2.26)	(2.00)	(1.29)
Walls and windows	0.153	0.108	0.180	0.130	0.101	0.121	0.177	0.155
(1 = yes)	(10.78)	(9.39)	(15.83)	(13.78)	(12.17)	(7.63)	(5.70)	(4.69)
Kitchen								
Good	0.052	0.102	0.057	-0.029	0.050	0.079	0.120	0.063
(1 = yes)	(6.26)	(15.58)	(7.10)	(4.63)	(8.55)	(10.52)	(10.07)	(4.31)
Excellent	0.089	0.179	0.165	0.066	0.124	0.164	0.232	0.183
(1 = yes)	(10.66)	(26.96)	(19.89)	(10.06)	(20.83)	(21.23)	(18.80)	(12.38)
Heating system								
Electric radiator	0.160	0.189	0.206	0.234	0.269	0.238	0.274	0.375
(1 = yes)	(8.01)	(14.84)	(13.83)	(16.97)	(19.01)	(15.43)	(10.95)	(9.05)
Electric furnace	0.189	0.229	0.270	0.298	0.310	0.251	0.327	0.430
(1 = yes)	(9.42)	(17.53)	(17.26)	(20.94)	(21.49)	(15.85)	(12.67)	(10.34)
Solar/other	0.173	0.180	0.204	0.242	0.256	0.220	0.263	0.335
(1 = yes)	(8.65)	(14.03)	(13.58)	(17.38)	(18.02)	(14.18)	(10.42)	(8.08)
Exterior steam	0.138	0.344	0.234	0.398	0.291	0.226	0.358	0.403
(1 = yes)	(6.80)	(26.27)	(14.16)	(27.23)	(19.27)	(13.78)	(11.99)	(9.28)
Other central heat	0.187	0.235	0.274	0.290	0.262	0.257	0.325	0.403
(1 = yes)	(9.19)	(16.96)	(16.23)	(18.80)	(17.82)	(15.05)	(11.41)	(8.72)
Wood burning stove	0.135	0.116	0.116	0.148	0.175	0.182	0.217	0.227
(1 = yes)	(6.08)	(8.53)	(7.06)	(8.38)	(11.45)	(10.93)	(7.73)	(5.33)
Roof								
Cement/steel	0.039	0.010	0.010	0.022	0.033	0.033	0.033	0.026
(1 = yes)	(16.57)	(4.39)	(2.71)	(7.87)	(12.38)	(10.80)	(7.09)	(5.52)
Slate/copper	0.089	-0.006	-0.044	0.002	0.014	0.002	0.020	-0.012
(1 = yes)	(9.25)	(0.67)	(3.85)	(0.20)	(1.78)	(0.17)	(0.95)	(0.55)

TABLE IV—Continued

	Region							
	I	II	III	IV	V	VI	VII	VIII
Other								
Distance to center ^c (Kilometers)	-0.008 (47.12)							
Urban area	0.131 (32.87)	0.061 (20.14)	0.062 (13.19)	0.130 (34.00)	0.083 (26.04)	0.079 (19.41)	0.110 (16.33)	0.161 (24.94)
(1 = yes)	2.255 (26.28)	3.641 (44.58)	3.409 (27.43)	3.177 (32.28)	3.427 (38.34)	3.422 (31.53)	3.369 (17.02)	3.136 (18.41)
Capital subsidy SEK	8.828 (122.30)	8.285 (109.81)	8.348 (58.83)	8.143 (73.07)	8.091 (103.61)	8.614 (71.85)	7.095 (35.43)	6.934 (33.97)
Intercept	0.762 74077	0.754 94943	0.726 53527	0.733 90741	0.758 106147	0.739 59821	0.76 23289	0.681 31349
Number of transactions	59330	75193	42837	70890	84697	48086	18396	24534
Number of dwellings	Panel B. Estimates of (10) and (11) Based on Residuals from Regression on All Multiple Sales							
β_d (annual rate)	0.0032 (4.47)	0.0047 (7.43)	0.0054 (5.68)	0.0093 (11.83)	0.0041 (5.72)	0.0067 (7.21)	0.0059 (3.83)	0.0023 (1.86)
ρ (quarterly rate)	-0.471 (6.63)	-0.171 (0.28)	-0.360 (1.92)	-0.390 (3.67)	-0.596 (21.79)	-0.413 (3.22)	-0.512 (5.55)	-0.353 (1.78)
	Panel C. Other							
σ_e^2	0.040	0.060	0.081	0.103	0.107	0.064	0.094	0.101
$\sigma_{e_2}^2$	0.013	0.013	0.016	0.021	0.017	0.016	0.019	0.018
$\sigma_{e_3}^2$	0.010	0.013	0.014	0.017	0.011	0.013	0.014	0.015
β_v (annual rate)	0.0032	0.0077	0.0084	0.0123	0.0071	0.0117	0.0109	0.0053
Capitalization rate (at cond. mean subsidy)	1.024	1.304	0.832	0.702	0.755	0.821	0.786	0.546

Notes: t -ratios are in parentheses. Price index estimates, P_t , are not reported.

^a Variable measured in logarithms.

^b Model also includes two dummy variables, one indicating lot sizes between 2500 m² and 5000 m², the other indicating lot sizes of 5000 m² or more.

^c Model also includes separate intercepts and distance variables for each of 111 labor market areas. Region I, Stockholm, is considered a single labor market area.

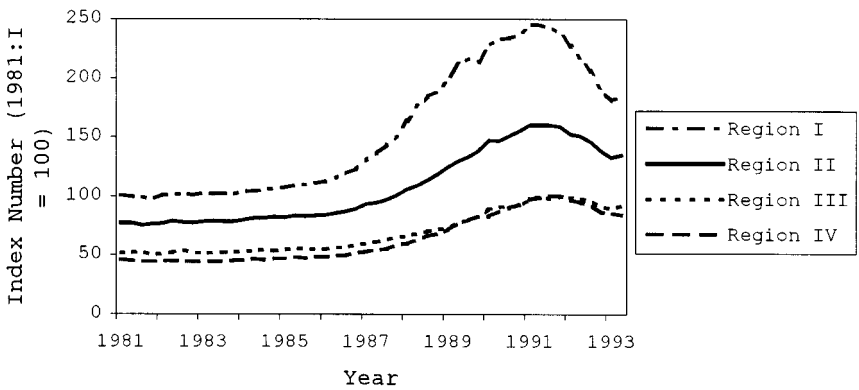


FIG. 2. House price indexes for Sweden, regions I-IV.

housing demand was the deregulation of the credit market beginning in 1985. Finally, a major tax reform cutting the marginal tax rate on interest deductions from 50 to 30% was announced in 1989 and implemented in 1991. Beginning in that year, prices fell in nominal terms (for the first time since World War II). Again several factors coincided: the tax reform, a major depression with a 5% decline in real GDP from 1990 to 1993, and

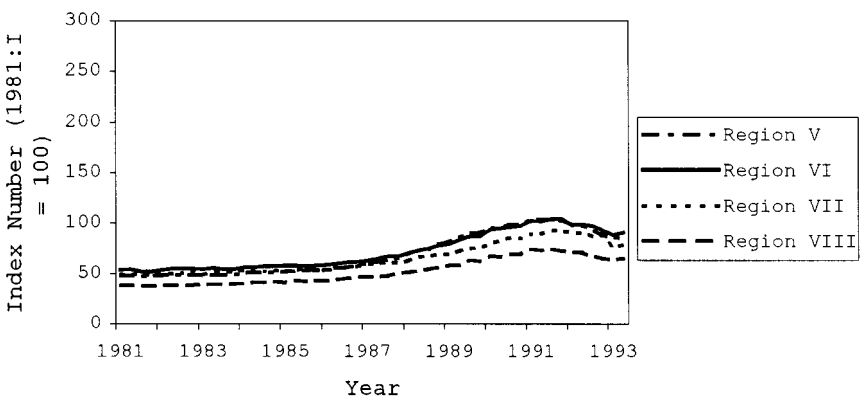


FIG. 3. House price indexes for Sweden, regions V-VIII.

TABLE V

Comparisons of Quarterly Percentage Changes in Real Housing Prices for EQR and SCB Indexes, 1986:I–1993:III

Region	Mean ($\times 100$)		Variance ($\times 10000$)		Serial correlation coefficient	
	EQR	SCB	EQR	SCB	EQR	SCB
I	0.302	0.247	15.512	17.834	0.777*	0.783*
II	0.170	0.061	7.200	9.642	0.662*	0.441**
III	0.279	0.129	4.789	8.192	0.398**	0.247
IV	0.421	0.388	8.665	10.340	0.522*	0.549*
V	0.152	0.111	9.181	11.955	0.523*	0.480*
VI	0.080	0.051	7.839	9.210	0.206	0.039
VII	-0.113	-0.220	13.160	7.279	-0.136	0.241
VIII	-0.069	-0.084	9.742	11.042	-0.108	0.022

Note: *-indicates significance at 1% level.

** -indicates significance at 5% level.

*** -indicates significance at 10% level.

sharply increasing real interest rates resulting from a disinflationary monetary policy.

It is possible to compare the price indexes developed here with the official index published by Statistics Sweden (SCB).¹³ Before 1986, the SCB index is only available annually, and the differences between SCB indexes and our indexes are small. There is some tendency in each of the regions for our index series to be leading relative to that of SCB. In Table V we summarize some key statistics of the two series for the eight regions. Over the whole period we find prices increasing somewhat faster in each region according to our methodology (“the EQR index”) than according to the SCB index. The variances are very similar for the two series, with the exception of one of the smaller regions, region VII.

An important use of housing price indexes has been to analyze the predictability of investment returns. Case and Shiller [6] and others found strong evidence of positive serial correlation for U.S. metropolitan areas, and Englund and Ioannides [8] documented the same pattern in nation-

¹³The SCB index is constructed using the assessed value of properties (presumably a hedonic relation based on expertise and judgment). Within each region, SCB divides all dwellings into 12 classes according to assessed value for tax purposes. The price index is constructed as a weighted average of the mean sales prices in the different assessed-value classes. The weights are given by the fraction of all properties (not just those transacted) within a particular size class.

wide price data (of varying quality) for a number of OECD countries. Here we find somewhat stronger evidence of (first-order) serial correlation according to our index than according to official statistics. While the SCB index exhibits significant positive serial correlation (at the 10% level) in four of the eight regions, ours is significant in five regions. The average point estimate of the serial correlation coefficient using the techniques developed in this paper is 0.153 compared with an average of 0.085 for the official SCB index. These differences suggest that the way we estimate price indexes may be crucial for any conclusions about the efficiency of housing markets.

VI. CONCLUSION

This paper introduces an improved methodology, combining cross sectional and panel data, for estimating asset prices for durables such as residential housing. The method distinguishes between the effects of observable and unobservable aspects of quality and between the effects of depreciation and vintage upon asset prices. The method also investigates price dynamics at the level of individual house sales.

The model is used to analyze the structure of housing prices in Sweden by investigating a rich body of data on all house sales in the country during a 12-year period. The empirical estimates confirm the importance of a host of quality and amenity measures in determining housing prices, the independent effects of depreciation and construction vintage, and the capitalization of interest rate subsidies. The results also suggest that unusually short turnover periods between sales of any house are associated with atypical price movements—reflecting distressed sales or uninformed initial offer prices.

Observable housing characteristics explain roughly three-quarters of the variation in housing prices in this rich sample of transactions. Another 19% of the variation in prices arises from unmeasured individual-specific variation, leaving only about 6% unaccounted for.

Price indexes for housing assets computed from these regressions reveal a similar pattern of price development across regions during the sample period—generally stable prices through 1987, followed by a roller coaster ride—with a peak in 1991 and free fall thereafter.

A comparison of these indexes with those published officially reveals some differences. The indexes produced by the methods outlined in this paper show higher average changes in quarterly prices and slightly higher serial correlation in quarterly prices. They also suggest that returns are more predictable—and the market is less efficient—than is revealed in official statistics.

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