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REVISITING THE PAST AND SETTLING THE SCORE: INDEX REVISION FOR HOUSE PRICE DERIVATIVES

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Revisiting the Past and Settling the Score: Index Revision for House Price Derivatives

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This article examines index revision in measuring the prices for owner-occupied housing. We consider revision in the context of equity insurance and the settlement of futures contracts. The usefulness of aggregate housing price indexes in these contexts requires stability as they are extended. Methods that are subject to substantial revision raise questions about the viability of derivatives markets. We find that the most widely used house price indexes are not equally exposed to volatility in revision. Hedonic indexes appear to be substantially more stable than repeat-sales indexes and are not prone to the systematic downward revision found in the repeat-sales indexes.

Most of the statistical series used to describe the workings of the economy are subject to periodic reexamination and reestimation. Indexes are revised when either the method used to incorporate data or the data themselves are updated. Index revision of the former type is illustrated by the changes in the Consumer Price Index (CPI) that arose from implementing the findings of the Advisory Commission to Study the CPI (the so-called "Boskin Commission"). In this case, the CPI was rebenchmarked through the adoption of new practices based on economic theory.[1] Index revision of the latter type results from the reestimation of the index after the arrival of new information.[2] We focus on index

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[1] The Boskin Commission identified four sources of potential bias based on observed behaviors of consumers: the substitution effect, the sample rotation effect, the outlet substitution effect and the quality-improvement effect. For more on these and the suggestions for revisions to the construction of the CPI, visit http://www.bls.gov/cpip/home.htm.

[2] Revision of this type can be found in the CPI as well. Each year with the release of the January CPI, seasonal adjustment factors are recalculated to reflect price movements from the just-completed calendar year. This routine annual recalculation may result in revisions to seasonally adjusted indexes for the previous 5 years.

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revision of this latter type. Revision from either source has direct implications for public policy and private investment; these indexes are relied upon in policy formulation, investment decisions and economic modeling, and they may form the basis for the development of markets for products such as housing price futures and home equity insurance.

Our interest is the dynamic performance of commonly used methods of housing price index construction: those based on repeat-sale and hedonic models. While there is an extensive literature on the asymptotic characteristics of these indexes, little is known about their stability as they are reestimated with the arrival of new information about housing prices. At issue is not the influence of observations that are added to the data due to informational lags. Rather it is the extent of index revision as additional sales are included in the set of observations used in their construction.

Index stability is often overlooked as a desirable characteristic of price indexes. This is especially relevant for house price indexes, given their wide use. Economic models of mortgage prepayment and default, measures of household wealth and cost-of-living calculations, among many other applications, are all informed by indexes based on the "latest" data. If, in fact, initial estimates of aggregate prices are subject to substantial revision, results from these models and measures may be misleading. Furthermore, the perception of instability in measured prices may preclude the development of markets for financial assets based on housing price indexes.

In the United States the only widely available set of quality-controlled housing price indexes are based on so-called repeat-sale models. We present extensive evidence on the extent to which revision for this class of indexes is "large." Our benchmark for making this assessment is a chained Fisher ideal index derived from a series of cross-sectional hedonic regressions. Repeat-sale indexes rely on strong assumptions regarding the time-invariance of both dwelling characteristics and their implicit prices in order to recover aggregate housing prices from a sample of dwellings that sell two or more times. In contrast, the chained Fisher ideal index is based on a series of cross-sectional regressions that employ all available information about housing sales, while allowing both housing characteristics and their implicit prices to change over time. We compare this benchmark index to two indexes based on repeat-sale models and one index based on a longitudinal hedonic model, where implicit prices of housing characteristics are assumed to remain constant over time.

We find that there are significant differences among the price indexes; revisions to estimated series are larger for indexes based upon repeat-sales models than those based upon the longitudinal hedonic model. Our benchmark index, the chained Fisher ideal index, is not subject to revision from the addition of new sales as the index horizon is extended. While larger in magnitude, we also find that revision to the repeat-sale indexes is systematically downward. Furthermore, we find that these indexes are subject to revision that can persist over several years. In some part, this arises because of the inherent nature of the information embodied in the arrival of an additional paired-sale: while one observation reveals information about current market conditions, the accompanying paired-sale reveals information about past prices. Moreover, the linked nature of the repeat-sale indexes implies that all previous index-level estimates are subject to revision whenever new paired-sales are added to the data set.

We also examine the impact of index revision in the context of home equity insurance. Home equity insurance schemes seek to reduce the exposure of homeowners to fluctuations in the values of their homes by developing a market for derivatives based on an index of local house prices. By trading in such an index, households may hedge their long positions in housing by taking short positions in contracts derived from local housing prices (Shiller 1993). The popular press has prominently featured discussions of this possibility,[3] and a pilot project is underway offering home equity insurance to homeowners in a large U.S. metropolitan area.[4] For home equity insurance to be attractive to homeowners, the reliability of the index is crucial. Preliminary price estimates must be credible, accurately reflecting systematic movements in local housing prices, period by period. Indeed, the integrity of the index may be the most important factor in developing a successful market for index swaps, futures or other derivative contracts that would reduce the risks of homeownership.

By construction, the chained Fisher ideal index is not revised as it is extended. In contrast, revision is an implicit feature of the other indexes we examine. We seek to establish whether the revision for any index is large enough to limit its usefulness. In particular, we ask whether the change over time in the estimated index and the length of time required to achieve a stable estimate of price levels are likely to inhibit the development of a market for contracts based on the indexes. More specifically, we address the question of whether the level of revision found in the repeat-sales indexes, which currently form the basis for regional house price measurement and provide the only feasible basis for index derivatives in the United States, will cause complications in practice. It would seem natural to settle insurance compensation on the basis of the index value at the date of the transaction. But if the index were subject to large revisions

[3] See, for example, *Forbes Magazine*, August 28, 2002, ww.forbes.com/2002/08/28/0829whynot.html.

[4] See Caplin *et al*. (2003) for an extensive description.

subsequently, any settlement may seem unfair or arbitrary in hindsight. We explore several approaches to contract settlement that may mitigate the impact of index revision.

This comparative analysis is only made possible with large samples of house sales and hedonic characteristics unavailable in the United States.[5] Thus, we rely upon a unique body of data that reports sales prices and hedonic characteristics for each of the 600,000 single-family dwellings sold in Sweden during the period 1980–1999. This body of data—detailed government records on dwelling characteristics and market transactions (maintained for national property tax administration in Sweden)—forms the basis for our empirical comparison.

Price Indexes for Housing

Housing values are reported in the units of price times quantity, so it is natural to consider a model,

$$\log V_{it} = \log P_{it} + \log Q_{it} + \varepsilon_{it}, \tag{1}$$

where V_{it} is the value of house i at time t, P_{it} is an index of house prices at t, Q_{it} is the quantity of housing (*e.g.*, the quality of the house) and ε_{it} is an error term. Of the variables in (1) only V is directly observable and only at the time of sale. We must use indirect statistical methods to disentangle the price index from the measure of quality.

Observable information about the hedonic attributes of dwellings and transactions dates yields an empirical relationship,

$$\log V_{it} = X_{it}\beta_t + D_{it}\delta_t + \varepsilon_{it}. \tag{2}$$

In this formulation, X_{it} is a vector of hedonic characteristics of dwelling i, and D_{it} is a vector of dummy variables with a value of 1 in the time period of sale and 0 otherwise. Further, β_t represents the implicit prices of hedonic characteristics at time t, and δ_t is the intercept at t; β and δ are estimated statistically by making suitable assumptions about the error term, ε.[6]

[5] Because the United States does not have a national real property tax, there is no administrative reason for assembling consistent national or regional data on hedonic attributes of houses and their sale prices.

[6] Of course, neither the set of X variables nor the log linear relationship represented by (2) is deduced from theory. For hedonic models of housing prices, there is some evidence that semi-log and Box-Cox specifications "do best" (Cropper, Deck and McConnell 1988). However, these complications—specification and choice of variables—are no different in this context than in other applications in economics.

In the simplest application of the hedonic model represented by (2), it is assumed that the vector of implicit prices of characteristics is time-invariant, that is, $\beta_t = \beta$ for all t. In this case, the time-varying intercepts (δ_t) have direct interpretations as index levels.[7] As implicit prices are stable, by assumption, all dwellings appreciate at the same rate irrespective of hedonic characteristics. The arrival of data in later time periods will increase the precision of the estimates of price indexes and implicit prices. Further, if the implicit prices are time-invariant, then estimates of β and of δ_t will only change because the arrival of new information increases the sample size. As data accumulate, revisions will be smaller, and sampling variances will be reduced. Estimates will converge toward the true parameter values.

However, the assumption that the implicit prices of housing attributes are stable has neither theoretical foundation nor empirical support. Nevertheless, even in that case an index based on stable hedonic prices need not yield biased estimates of aggregate housing prices. Only if the implicit prices change in a systematic fashion will the covariance between time and attributes have a systematic impact on the price index estimates.

With large samples it is possible to estimate (3) for each temporal cross-section:

$$\log V_{it} = \delta_t + X_{it}\beta_t + \varepsilon_{it}. \tag{3}$$

An index may then be constructed by pricing a constant-quality dwelling in each period, valuing it based on the implicit attribute prices estimated in (3). In this approach, the choice of the representative dwelling can have an important impact on the estimated index. The choice of a "standard" house is typically either the average in the initial or final period, yielding Laspeyres or Paasche indexes, respectively. A Fisher ideal index is the geometric average of the Laspeyres and Paasche indexes. Equation (3) and the Fisher ideal index form the basis for the national index of new single-family home prices currently produced by the U.S. Census (Moulton 2001).

The benchmark index used in this article is a chained version of the Fisher ideal index proposed by Thibodeau (1995). In this application, we estimate period-by-period changes in aggregate housing prices, "chaining" each periodic price change to the existing index. Here, the Laspeyres and Paasche indexes are constructed for adjacent periods, with the "standard" dwelling for each index being defined by the average characteristic bundle of the dwellings sold in the

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[7] Because the specification includes an intercept, the price index, I_t, is merely $\exp(\delta_t)$. The price index for period $t = 1$ is 1.00.

first and second of the two adjacent periods, respectively. The adjacent periods are the last period covered by the existing Fisher price index and the new period to be appended to it. The Fisher index is the geometric average of the one-period change in house price as measured by the Laspeyres and Paasche indexes. This change is then applied to the current level of the chained Fisher index to arrive at the updated index. Clearly, this procedure precludes revision of past index values.

In the absence of measures of hedonic characteristics, price indexes may be constructed based on transactions of the same dwelling at two points in time, t and τ. Taking the difference of (3) yields

$$\log V_{it} - \log V_{i\tau} = X_{it}\beta_t - X_{i\tau}\beta_\tau + D_{it}\delta_t - D_{i\tau}\delta_\tau + \varepsilon_{it} - \varepsilon_{i\tau}. \tag{4}$$

Two further assumptions make the estimation tractable without hedonic characteristics: unchanged quality of dwellings, $X_{it} = X_{i\tau}$; and unchanged implicit prices, $\beta_t = \beta_\tau$. Under these circumstances, the log difference in sales prices is related only to the dummy variables identifying the timing of the first and second sales, and Equation (4) simplifies to

$$\log V_{it} - \log V_{i\tau} = D_{it\tau}\delta + e_{it\tau}. \tag{5}$$

Here D is a matrix of dummy variables taking a value of -1 in the period of the first sale, $+1$ in the period of the second sale and 0 otherwise. This method of producing house price indexes was first proposed by Bailey, Muth and Nourse (1963).

It is likely that some dwellings have different characteristics at the two sale dates, violating one of the assumptions required for the consistency of the repeat-sales approach. If data on hedonic characteristics are available, repeat-sales indexes can include dwellings that have been modified between sales by including the changes explicitly in the regression:

$$\log V_{it} - \log V_{i\tau} = (X_{it} - X_{i\tau})\beta + D_{it\tau}\delta + e_{it\tau}. \tag{6}$$

Note again that hedonic prices are assumed to be constant over time.

We estimate Equations (2)–(6) using sales over a 19-year period. From these statistical models, we compute four indexes of housing prices based upon repeat-sale and hedonic methods.

Index 1 is a repeat-sales index based on Equation (5). It assumes that neither the physical characteristics of the dwelling nor the implicit characteristic prices are changed between sales. This "naïve" index is analogous to the most widely used regional housing price indexes in the United States.[8]

Index 2 is based upon Equation (6), a repeat-sales model in which all changes in the hedonic characteristics of dwellings are explicitly controlled for, but in which hedonic prices are assumed to be constant.[9]

Index 3 is based upon the hedonic method reported in Equation (2), but it imposes the restriction that the implicit prices of the hedonic characteristics are time-invariant. We refer to this model of housing price as the "longitudinal hedonic" model.

Index 4 is based upon Equation (3), estimated separately for each time period. Index 4 is the chained Fisher index, constructed from a series of geometric averages of Paasche and Laspeyres indexes estimated over adjacent time periods.

Note that the statistical models are clearly nested. A comparison of Indexes 3 and 4 permits a test of the importance of changes in the prices of hedonic characteristics over time in explaining the course of prices.[10] A comparison of Indexes 1 and 2 permits a test of the importance of changes in the hedonic characteristic of dwellings between sales and dates in explaining the course of prices.

Whatever the index, revision arises from the arrival of new information in the form of dwelling sales. The indexes derived from the repeat-sales model are

[8] The Office of Federal Housing Enterprise Oversight (OFHEO) house price indexes for states and metropolitan areas are based on Equation (6), the repeat-sale index technique first introduced by Bailey, Muth and Nourse (1963). The so-called "weighted repeat-sale" (WRS) approach, developed by Case and Shiller (1987), assumes a random-walk rather than mean reversion in the error structure. For more details on the WRS approach and its application by OFHEO, see Calhoun (1996; http://www.ofheo.gov/house/hpi_tech.pdf). For details on a commercial application of the WRS, see http://www.cswv.com/products/redex/case.

[9] Englund, Quigley and Redfearn (1999) explore in more detail the relationship between the samples of paired sales with and without verification of the constant quality assumption. They find aggregate quality-improvement over time and a significant overstatement of housing prices in the naïve (unverified assumption of constant quality) sample relative to the unchanged (verified) sample. This bias is attributable to unmeasured quality change. They do not investigate the influence on index revision.

[10] If hedonic prices are stable, then it is more efficient to pool the data and estimate hedonic prices over the whole sample. Alternatively, if implicit prices are time varying, it is necessary to estimate cross-sectional regressions. Our results clearly indicate that implicit prices are unstable, which thus justifies the cross-sectional approach. The formal test of stable implicit prices has previously been employed for the same purpose by Crone and Voith (1992), Meese and Wallace (1997) and others. Like them, we reject the temporal stability of the hedonic prices on housing attributes.

particularly exposed to revision because they utilize paired-sales—two sales of the same dwelling at different points in time. Thus, when observations for a new period are added to a repeat-sales database, they will augment not only sales prices in the new period, but also purchase prices in earlier periods. Thus, all previous index estimates will be revised in light of this new information.[11]

The Data and an Overview of Swedish Housing Prices

We rely upon data describing all sales of owner-occupied single-family dwellings in Sweden during the 19-year period, 1981–1999. They are compiled by Statistics Sweden by merging two sources: tax assessment records, which contain physical characteristics of the dwellings, and sales records, which contain dates of sale and transactions prices. Dwellings are assigned a unique identification number, making it possible to identify multiple sales of the same dwelling. The detailed physical description of each dwelling enables verification of the assumption that quality remains constant between sales. Transactions between family members have been eliminated, and the data set is confined to arm's-length transactions, as far as can be ascertained. The data sources are described more fully in Englund, Quigley and Redfearn (1998).

In the full data set there are nearly 1,000,000 transactions involving more than 600,000 dwellings. These data are reported separately for eight administrative regions. Only the Stockholm metropolitan region covers a single-housing metropolitan market, and we restrict the analysis in this article to this region. The distribution of dwellings by the number of times they are sold during the sample period is reported in Table 1. It shows that almost a third of all dwellings that transacted were sold more than once during the 19-year period, and multiple sales constitute more than half of all transactions. The owner-occupied housing

[11] An example may illustrate the importance of this new information in revising the index. Assume there are three samples of repeat sales from two periods. Assume dwellings in sample A were sold at time 0 for an average price of 100 and at time 1 for an average of 110. This yields a price index estimate of 110 in period 1. Houses in sample B were sold at time 1 for 110 and at time 2 for 125. With no other observations, the augmentation of sample A with sample B will provide a price estimate of 125 for period 2 and with no need to revise the index for period 1. Now assume that we also observe a sample C of houses that sold at time 0 for 100 and at time 2 for 150. The new price information from the long-interval repeat-sale sample C suggests that the price increase between time 0 and time 2 is greater than is indicated by samples A and B. Hence, further augmentation of samples A and B with sample C will cause the index for period 1 to be revised upward. Estimates of the new index values will be a weighted average of the original estimate 110, and the period 1 estimate implied by the combined sample of B and C. Note that revisions will be systematic if dwellings with long holding periods appreciate at a rate that is different from houses with short holding periods: if long-interval sales typically exhibit higher (lower) average rates of price increase, then upward (downward) revisions will be the norm.

Table 1 ■ Dwellings by frequency of sale.

Number of Sales	Dwellings	Transactions
1	61,614	61,614
2	22,815	45,630
3	7,037	21,111
4	1,728	6,912
5	346	1,730
6	39	234
7	4	28
8	1	8
Total	93,584	137,267

stock in Stockholm during this period averaged over 200,000 units. We observe 93,584 sales of distinct units, or almost half of the entire owner-occupied housing stock.

Englund, Quigley and Redfearn (1998) present a hedonic model of housing prices which relates measures of size, age, amenities, quality and location to the selling prices of Swedish dwellings. All specifications of the hedonic models presented below are based upon regressions including these measures. Column 1 of Table A1 in the appendix presents summary information on these hedonic attributes. In the empirical analysis, time is expressed in quarter years, and estimates of quarterly price indexes for dwellings are presented.

Figure 1 reports the estimated price levels for five indexes: the longitudinal hedonic model, the chained Fisher index based on cross-sectional hedonic regressions, the naïve and hedonic-adjusted weighted repeat-sale indexes, as well as median sales prices. The indexes reflect the broad evolution of prices in Stockholm over the 19-year time period, and the patterns are similar. Figure 2 shows each index relative to the chained Fisher ideal index; it makes clear that the indexes are far from identical.[12]

The repeat-sales indexes differ significantly from the chained Fisher ideal index and from the other hedonic-based indexes. By the end of the sample period, the repeat-sales index with hedonic adjustment exceeds the chained Fisher ideal index by over 10%. The "naïve" repeat-sales model lags the Fisher ideal index during the middle of the sample period by approximately 3%, but by the end of the time series it exceeds the Fisher index by 6%. The remarkable similarity

[12] The null hypothesis that the repeat-sale and hedonic indexes are indistinguishable from one another can be rejected at standard levels of significance.

Figure 1 ■ Price indexes of the stockholm region 1981–1999.

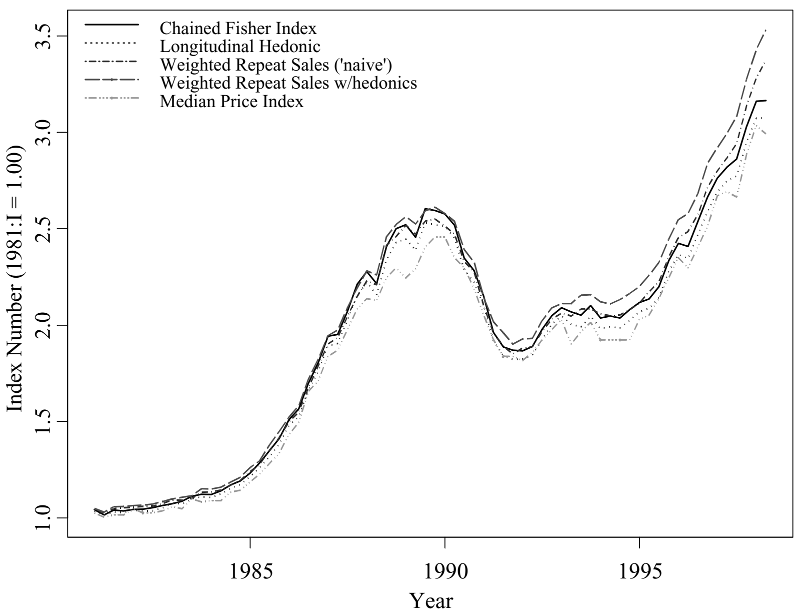
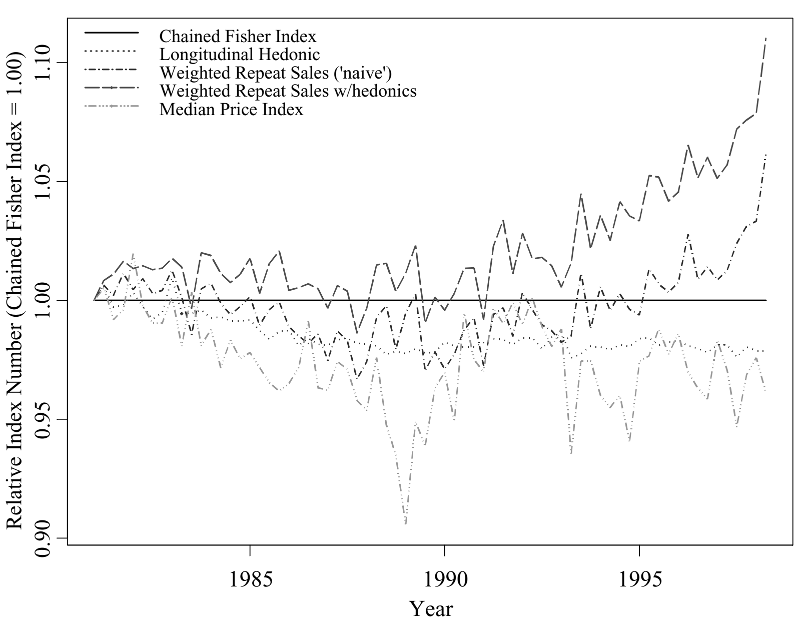


Figure 2 ■ Price indexes relative to the chained Fisher ideal index.



of the longitudinal and chained Fisher indexes may be surprising given the clear rejection of the implicit assumption of fixed hedonic prices over time (see footnote 10). The similarity suggests that temporal variation in attribute prices is not systematically correlated with time.[13]

It is worth comparing the quality-adjusted indexes to the simple median sales price index, which is also included in Figures 1 and 2. The median is commonly used when more precise hedonic information is unavailable. The most well-known example in the United States is probably the median price index produced by the National Association of Realtors. The main disadvantage of the median index is that it is not quality-adjusted, implying that an increase in the median index may reflect either a higher price for a constant-quality unit or quality variation in the sample of sold dwellings from period to period.

On theoretical grounds, the median index is therefore undesirable for contract settlement. Nevertheless, it is easy to compute and simple to understand. Moreover, the median index is not subject to revision. Figure 2 also compares the median index relative to the Fisher ideal index. As can be seen, the median and Fisher indexes at times diverge, especially so during the peak of the house price cycle around 1990. Despite the lack of quality control in the median price index, it is worth noting that it appears no worse than the index based on repeat sales with hedonic adjustment.

These indexes are based on all data that are available between the first quarter of 1981 and the fourth quarter of 1999. Neither Figure 1 nor Figure 2 indicates the extent to which the estimates of prices change as new information arrives with additional sales. We now consider the evolution of the indexes over time when new information is incorporated into existing indexes.

Aggregate Price Indexes and the Sources of Revision

All four of the quality-controlled housing price indexes examined in this article are based on hedonic models. But because each makes selective use of the available data on sales and imposes different assumptions about the bundle of attributes and their implicit prices, estimated aggregate housing prices can vary across indexes. These distinct approaches to index construction also result in differences in the exposure to revision. While revision ultimately arises from new dwelling sales, the differences in measured revision arise from variations

[13] As reported in Table A1 in the appendix, the averages of the implicit prices from the cross-sectional hedonic regressions are similar to those from the longitudinal hedonic regression. However, the temporal variation in the hedonic prices is apparent in the relatively large standard deviations of the cross-sectional coefficients.

in the way that this new information is incorporated into index estimates.[14] This section examines the mechanics of revision for the four quality-controlled indexes.

In the case of the longitudinal hedonic index, new sales observations are pooled with existing data and the model coefficients are reestimated. Both the implicit prices of the dwelling characteristics and time indicators (from which price indexes are constructed) are revised. If the assumption of time-invariant coefficients (made when pooling sales from across different time periods) is appropriate, revision represents more accurate estimation as standard errors decrease. However, if this assumption is inappropriate, changes in the implicit prices over time are reflected in the estimates of the time dummies, and index revision represents an evolving bias resulting from model misspecification.

The chained Fisher ideal index is the geometric average of the Paasche and Laspeyres indexes estimated over adjacent periods, so revision in the chained Fisher cannot arise due to the extension of the index with the passage of time. Both the Paasche and Laspeyres indexes are based on a series of cross-sectional hedonic regressions that once estimated are not recalculated—revision cannot arise from reestimation.

For the repeat-sales indexes, additional observations on paired-sales over time include sales in the current period as well as their associated sales in the past. An updated repeat-sales index then incorporates new information about current selling prices as well as prices in the period of the earlier paired-sale; the nature of the repeat-sales approach implies that these indexes are subject to revision in every period.

As the sample period is extended, some dwellings sell a second time during the sample period. This results in an additional observed sale in the current period as well as an additional sale in the period of the pair's first sale, yielding a larger sample from which to estimate past prices. Figures 3 and 4 illustrate how the sample of repeat sales in any quarter changes as the sample period is extended.

Figure 3 plots the percentage of the dwelling stock available for use in index estimation at each quarter from 1986:I (quarter 21) through 1999:IV (quarter 76).

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[14] Indeed, we are interested in the relative stability as new sales data become available. Others have examined the revision due to the lag between sale date and the date the data become available for use in index construction. Butler, Chang and Crews-Cutts (2005) find a significant upward revision that effectively is complete over 1 month. Their focus was on the OFHEO indexes and the lag between the origination of a mortgage and the date it is sold to the GSEs. Their finding of downward revision may be an indication of "creaming" on the part of mortgage sellers. There is no such lag in our data set; a dwelling enters the data at the date of sale.

Figure 3 ■ Evolution of repeat-sale sample size for various time intervals as a percent of dwelling stock.

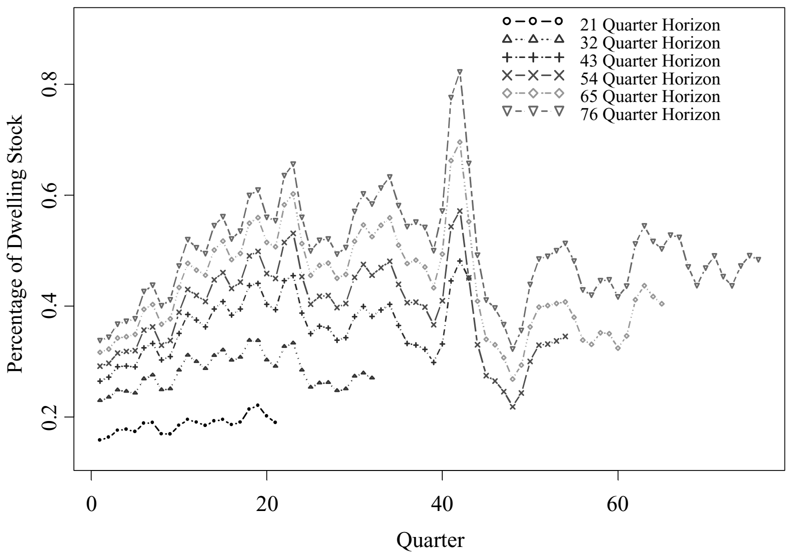
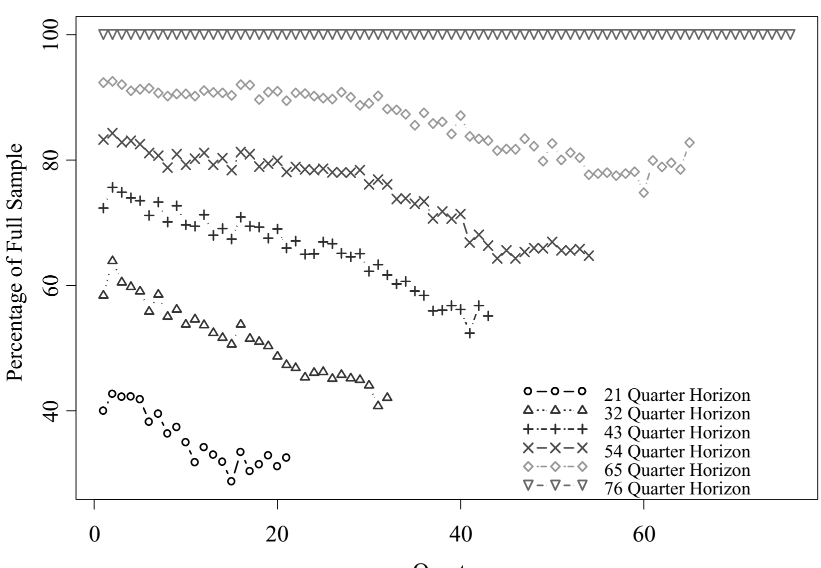


Figure 4 ■ Evolution of repeat-sale sample size for various time intervals as a percent of full sample.



The lines running roughly horizontally represent quarterly subsamples of sales at various sampling periods. For example, the line at the bottom of the figure shows quarterly sales, as a percentage of the stock of dwellings, observed in each quarter when data are sampled in quarter 21; the top-most line reports the percentage of the housing stock represented by the full quarterly samples using all of the available data (through 76 quarters).

In addition to the sample evolutions, Figure 3 also shows substantial variation in quarterly sales activity over time. In particular, the data exhibit a strong seasonality in dwelling sales, with troughs typically in the first quarter and peaks in the second quarter. There is also some longer-term variation, with a gradual increase in number of sales during the boom of the late 1980s and a general decrease accompanying the downturn in the early 1990s.[15]

It is clear from the figure that only a small portion of the dwelling stock is used in the construction of a repeat-sales price index. It shows, for example, that the share of the stock available to estimate prices using repeat-sales indexes in quarter 21 is less than 0.2%; 50 quarters later the proportion of the dwelling stock included in the repeat-sales sample for this quarter doubled to more than 0.6%. Further, the initial share tends to increase over time as the sample grows, being less than 0.2% for the first 20 quarters but generally above 0.4% beyond quarter 60.

Despite the ever-increasing size of the repeat-sales sample, approximately five in six of all dwellings are *not* found among the quarterly samples shown in line indicating the full repeat-sales sample (the top line in Figure 3). In other words, when estimating aggregate housing prices during this 19-year period, the repeat-sales sample includes observations on only about one-sixth of the housing stock. Over the same period, roughly half of the stock is traded at least once, but only dwellings sold two or more times are used in the constructing the repeat-sales indexes.

Figure 4 rescales the data in Figure 3 to underscore the exposure the repeat-sale indexes face from the arrival of new information about past prices. Figure 4 uses the full repeat-sales sample—those paired-sales observed through 76 quarters—as a benchmark to illustrate the evolution of quarterly subsamples. That is, the horizontal line at 100% indicates that all of the appropriate paired-sales available in the 19-year sample are used to estimate prices for the entire 76-quarter sample period. The lines below this benchmark are thus the percentages

[15] The peak in the first two quarters of 1991 is explained by the tax reform effective in January 1991 that reduced the tax rate on capital income (including capital gains on house sales) from 50% to 30%.

of the full sample that are available to estimate prices in earlier quarters. Figure 4 shows, for example, that the initial estimate of prices in quarter 21 is based on 40% of the number of sales in that quarter available by quarter 76. If the first 40% of the sales in the quarter differ in average appreciation from the remaining 60%, revision will occur. This can be contrasted with the data sets used in the hedonic indexes. Where the repeat-sale indexes are significantly exposed to revision from the arrival of new information about the past, the data used to construct the hedonic indexes are unchanging over time.

Quantifying Revision

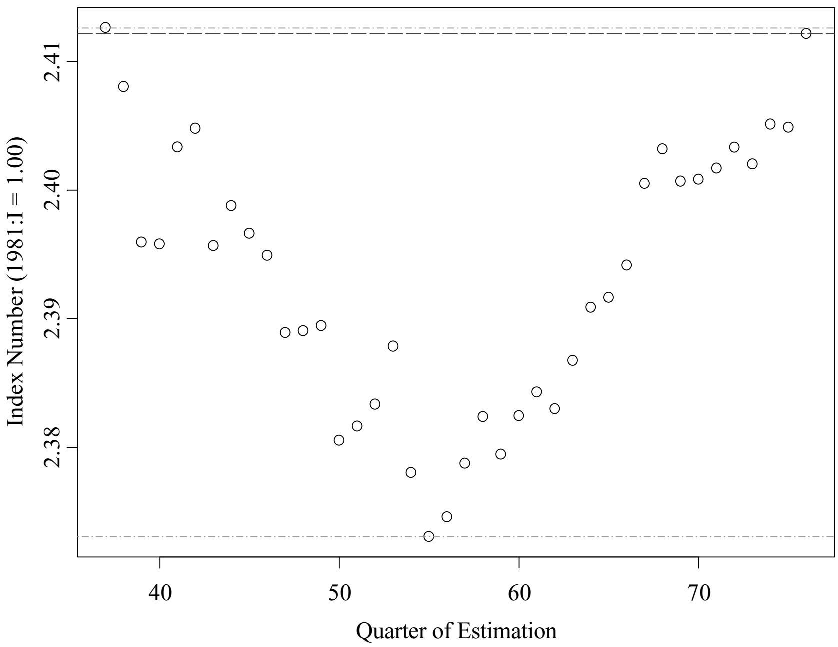
The general issue of index revision for repeat-sales indexes has received limited previous attention. Abraham and Schaumann (1991) analyzed repeat-sales data from Freddie Mac and Fannie Mae, finding that index revisions are significant (on the order of 10% in certain cases) even with large samples. Hoesli, Favarger and Giaccotto (1997) also reported sizeable revisions based upon a smaller body of multiple sales for Geneva. Clapp and Giaccotto (1999), in the most comprehensive study on index revision, highlighted the role of "flip sales," that is, transactions with very short holding periods. They showed that the extent of price revision in housing is reduced considerably if samples are confined to dwellings sold after intervals of 2 or more years.[16] This suggests that there is a link between the index revision and the sample selectivity of repeat-sales data. Several authors, including Clapp and Giaccotto (1992), Case, Pollakowski and Wachter (1997) and Gatzlaff and Haurin (1997), have found that smaller properties—"starter homes"—trade more frequently than houses in general. This indicates that index revision may be related to differences in price development between starter homes and other properties.

The empirical issue we consider is whether the index revisions are "large." In this section, we compare the magnitudes of revision among our four indexes. In the following section, we make inferences about the relative usefulness of indexes based on hedonic methods and those based on repeat sales for contract settlement.

We define "revision" as a change in estimated price levels that results from the remeasurement that occurs when new information is revealed in the form of additional sales. For the indexes based on repeat sales, revision results from the addition of new paired-sales to the sample—paired-sales that contain information

[16] We also find that the removal of short-hold paired sales reduces the magnitude of revisions. However, we find that the pattern of revision is still significant. Moreover, we fail to observe a natural cutoff between "short" and "typical" holding periods. Removal of the short-holds seems *ad hoc* for this particular sample.

Figure 5 ■ Estimated path of revision, quarter 37 (1990:I).



about both current and past prices. "Revision" is then the change in measured housing prices as they are recalculated using the new, appended data sets. We define an estimate of the price level in period t using information extending from an "initial" period 1 to the "current" period τ as P(t, 1, τ), where $\tau \geq t$. Revision is the process as the estimated index evolves from the initial estimate P(t, 1, t) to a current estimate P(t, 1, T), as data are extended beyond the initial period t. Tracking the time series evolution of the index estimates from "initial" to "current," that is, for $\tau = t, t + 1, \ldots, T$ yields a revision path. Examples of revision paths using the "naïve" repeat-sales index are shown in Figures 5–8.

These figures demonstrate the systematic remeasurement of parameter estimates from their "initial" to "current" values. For example, Figure 5 reports that the "initial" estimate of the aggregate price level in 1990:I was just over 2.41. Subsequently, as sales occurred in the following period, these data and their associated paired-sales were added to the data set, and prices were remeasured. As of 1991:I, the "current" estimate of the aggregate price level in 1990:I was under 2.41. Index revision is this change in estimated prices due to remeasurement.

Figure 6 ■ Estimated path of revision, quarter 45 (1992:I).

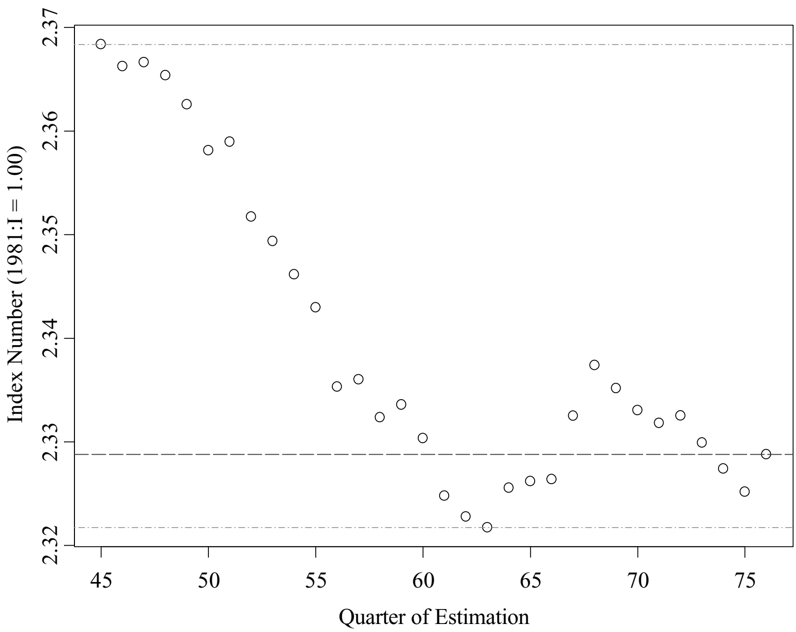


Figure 7 ■ Estimated path of revision, quarter 50 (1993:II).

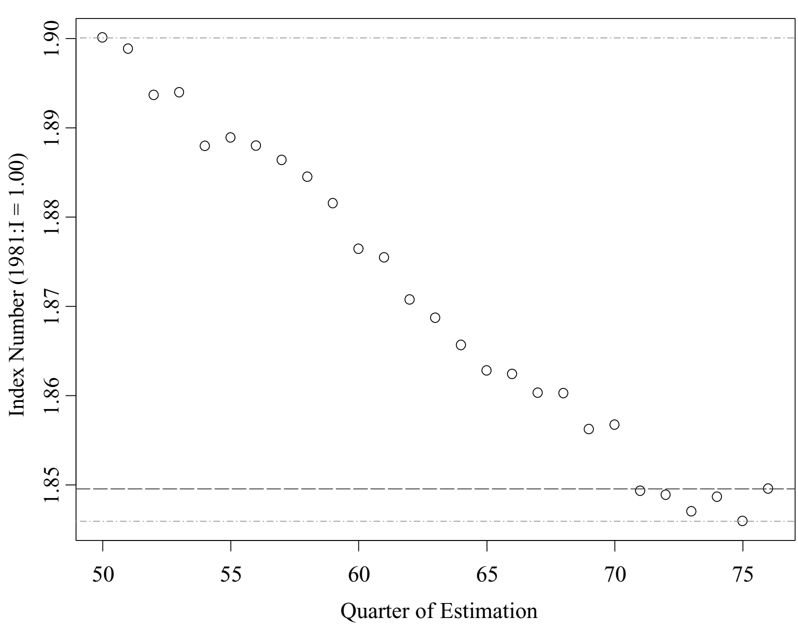
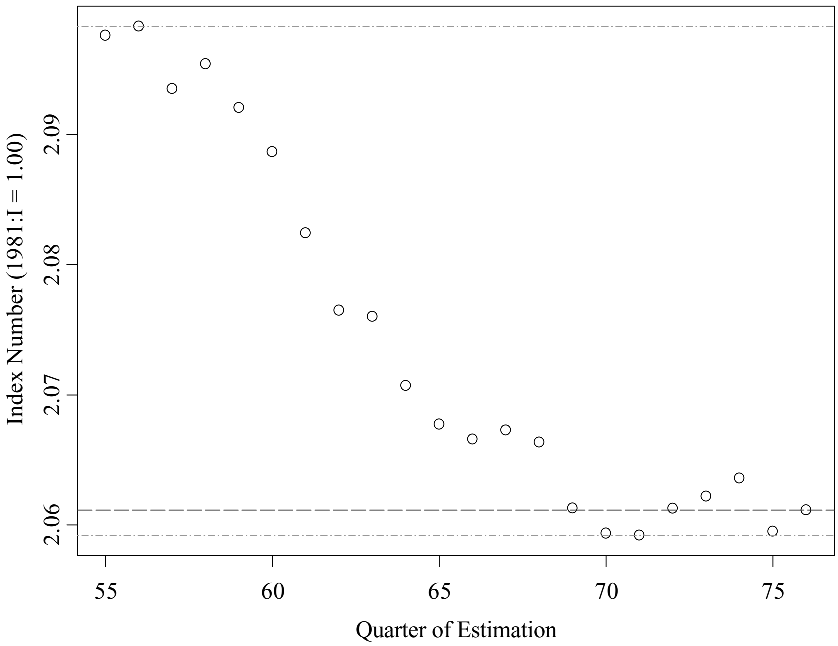


Figure 8 ■ Estimated path of revision, quarter 55 (1994:III).



Figures 5–8 show clear trends in revision resulting from the arrival of new information; the revision paths do not appear to be random. The figures suggest that revision is generally downward; "initial" estimates are higher than "current" estimates. This indicates systematic differences in the rates of price appreciation between the first sets of paired-sales relative to those that enter the data set later. Downward revision is not universal, however, as is evident in Figure 5. All four figures show economically and statistically significant revision in the level of prices and revision paths that last many years. Figures 6 and 8 suggest that the current index estimates have reached apparent stability, with estimates over the past several years relatively close to the current estimate. This is less clearly apparent in the revision paths shown in Figures 5 and 7, even after years of data.

These figures also underscore the need for care in the interpretation of summary measures of the extent of index revision. Figure 5, for example, illustrates a revision dynamic that would be greatly understated by comparing initial and current index estimates. We present several measures of index revision in Tables 2 and 3 that summarize these dynamics.

These measures are derived from the estimated housing price indexes using our data on sales spanning the period of 76 quarters, 1981–1999. We estimate

Table 2 ■ Index revision: quarter-by-quarter. Percent change in price level estimate relative to previous estimate (percent change at quarter $s = 100 \times [P(t, 1, s)/P(t, 1, s-1) - 1]$; $t = 31, \ldots, 51$, $s = t + 1, \ldots, t + 24$).

	All Revisions (%)		Early Revisions[a] (%)		Late Revisions[a] (%)	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Index 1: WRS (naïve)	−0.07	0.51	−0.11	0.24	−0.05	0.15
Index 2: WRS (with hedonics)	−0.10	0.65	−0.17	0.41	−0.06	0.18
Index 3: Hedonic (longitudinal)	−0.04	0.31	−0.04	0.02	−0.04	0.02
Index 4: Hedonic (chained Fisher)	–	–	–	–	–	–

[a]"Early" is defined as the first 10 revised index values; "late" as the remaining 15.

Table 3 ■ Index revision: cumulative change from initial to current estimates. Percent change in final price level estimates relative to initial estimate (percent change $= 100 \times [P(t, 1, t)/P(t, 1, t + 24) - 1]$; $t = 31, \ldots, 51$).

	Average (%)	Min. (%)	Max. (%)	Std. Dev. (%)
Index 1: WRS (naïve)	−1.72	−2.87	−0.21	0.69
Index 2: WRS (with hedonics)	−2.38	−4.84	−0.56	0.91
Index 3: Hedonic (longitudinal)	−1.03	−1.84	−0.35	0.51
Index 4: Hedonic (chained Fisher)	–	–	–	–

indexes using a rolling sample interval, beginning with $T = 31$ (1987:III) and ending with $T = 76$ (1999:IV). That is, we start with a subsample restricted to all sales up to and including 1987:III, and we estimate price indexes using the appropriate observations from this sample (all sales for the hedonic-based indexes, paired-sales for those based on repeat sales). We then extend the sample interval quarter by quarter, amend the samples accordingly and reestimate the price indexes. This is repeated until the last period, 1999:IV. We then extract comparable revision paths—the first 25 estimates of aggregate price levels for quarters 31–51, that is, $P(t, 1, t), P(t, 1, t + 1), \ldots, P(t, 1, t + 24)$ for $t = 31, 32, \ldots, 51$. By doing so, we are able to compare the behavior of the price level revision paths across index models.

The statistics in Table 2 focus on the panel of period-by-period index revisions (25 revisions to each of the price level estimates for quarters 31–51). The average quarterly revision is generally small, but it is larger for the repeat-sales indexes than for the hedonic indexes. The standard deviations indicate wide variation along the revision paths and substantially wider revision, by a factor of 2, for the repeat-sale indexes when compared to the longitudinal hedonic index. These figures indicate that initial estimates provided by repeat-sales indexes are less stable and are far more likely to be revised significantly relative to the indexes based on hedonic approaches.

Table 2 also shows the extent to which the revision of price indexes occurs in periods immediately following initial estimation. It reports the mean and standard deviation of the "early" and "late" revisions—changes in the first 10 and remaining 15 price level estimates, respectively. For the repeat-sales indexes, more significant revision occurs in the early quarters than in the later; periodic revision is larger on average and more varied over the first ten estimates. Conversely, there is essentially no change in the typical revision for the longitudinal hedonic index from early to late estimates and, of course, no revision in the chained Fisher index.

In order to assess index quality, it is important to distinguish short-run noise from long-run tendencies. Long-run trends in revision to the four indexes are illustrated in Table 3. This table reports summary statistics for the current estimates of the price levels at $T = t + 24$ relative to the initial estimates at $T = t$. Table 3 confirms that there is a clear tendency for the repeat-sales indexes to be revised downward, on average by 2.4% and 1.7%, respectively. There is a wide range around these averages, extending to a maximum cumulative downward revision of 4.8% for the repeat-sales index with hedonics. The amount of cumulative revision for the longitudinal hedonic index, by comparison, is rather small, −1.0% and +0.6%, respectively. The range around these averages is only about a third to half the range for the repeat-sales indexes.[17] The observation that downward revisions of repeat-sales indexes are more common than upward revisions confirms earlier results by Clapp and Giaccotto (1999).

In order to understand better the impact of quarterly revision on overall index stability, it is useful to recast the statistics in Tables 2 and 3, which report the *extent* of revision, to demonstrate the *incidence* of revision of particular magnitudes. If a futures market requires index stability, it would be useful to know how often revision, either period by period or cumulative, exceeds some level. Say, for example, that futures markets could tolerate 0.5% revision in any one quarter and 2% cumulative revision to the initial estimate—how often do the four indexes violate these criteria? We address this question in Tables 4 and 5.

[17] The repeat-sales index appears to perform worse with hedonic information included. This may reflect the maintained assumption of constant implicit prices.

Table 4 ■ Frequency that quarterly revision exceeds some limit (limit exceeded at quarter s if $(100 \times [P(t, 1, s)/P(t, 1, s-1) - 1]) > L$; $t = 31, \ldots, 51$).

	Limit and Frequency Exceeded			
	0.10%	0.25%	0.50%	1.00%
Index 1: WRS (naïve)	100%	100%	57%	10%
Index 2: WRS (with hedonics)	100%	95%	76%	24%
Index 3: Hedonic (longitudinal)	33%	0%	0%	0%
Index 4: Hedonic (chained Fisher)	0%	0%	0%	0%

Table 5 ■ Cumulative index revision limits. Frequency that cumulative revision exceeds some limit (limit exceeded at any quarter s if $\text{abs}(100 \times [P(t, 1, s)/P(t, 1, t) - 1]) > L$; $t = 31, \ldots, 51$; $s = t + 1, \ldots, t$).

	Limit and Frequency Exceeded			
	0.50%	1.0%	2.0%	3.0%
Index 1: WRS (naïve)	90%	90%	33%	0%
Index 2: WRS (with hedonics)	86%	48%	0%	0%
Index 3: Hedonic (longitudinal)	62%	24%	0%	0%
Index 4: Hedonic (chained Fisher)	0%	0%	0%	0%

In Table 4, periodic revision limits are set, and the frequencies that quarterly changes in price level estimates exceed these limits are tabulated. There is a far greater frequency of significant quarterly revision for the repeat-sales indexes. While over no two quarters is the longitudinal hedonic index revised by more that 1%, revision occurs in 25% of the quarters for the repeat sale with hedonic adjustment and 10% of the quarters for the standard repeat-sale index. These changes are compared with the benchmark index, the chained Fisher index, which is time-invariant.

Table 5 reports an analogous set of frequencies for cumulative revision. These figures are perhaps more relevant for contract settlement. If, for example, the standard for an index requires cumulative revision of no more than 2% *at any point* after initial estimation, the table indicates that neither of the repeat-sale indexes is adequate. Of all revision paths estimated using repeat-sales index with hedonic controls, 62% vary by at least 2% at some point over the 25 quarters examined; this frequency is 33% for the standard repeat-sales index. For the tighter standard of plus or minus 1% relative to the initial price level estimate, the repeat-sales indexes fails consistently whereas the longitudinal hedonic produces a revision path that exceeds this level in just less than one-half of the cases.

We can compare the magnitudes of revision in the housing price indexes with other widely accepted indexes. In particular, these revisions may be compared to revisions in the chained CPI in the United States.[18] Currently, the Bureau of Labor Statistics publishes initial, interim and final index figures. Generally, the update from initial to interim and from interim to final is available at the beginning of the following calendar year. The relative changes in the index levels are approximately 0.2% for both revisions (Bureau of Labor Statistics 2003). These are changes for the seasonally unadjusted series; the revisions in the seasonally adjusted series are larger and continue for 5 years. The revisions in our longitudinal hedonic index are slightly larger than for the unadjusted U.S. CPI, but still roughly comparable. The repeat-sales indexes display revisions of an entirely different magnitude. The 2–4% revision that can occur in a repeat-sales index is a good bit larger.[19]

Contract Settlement

Index revision may pose a significant impediment to the development of equity insurance products or futures markets based on aggregate housing prices. For example, consider a house that is purchased today for $400,000, corresponding to the median price in San Diego County or in affluent Stockholm suburbs like Djursholm or Lidingö. Suppose the owner purchased equity insurance to protect himself/herself from metropolitan-level shocks to housing prices. Over the next year, the price index, based on initial estimates, remains unchanged. At the end of the year, the owner sells his or her house at a loss.[20] Because the

[18] The revisions in that index occur for reasons that are technically different from the Fisher index discussed above. In particular, the cost-of-living approach used to compute the CPI utilizes expenditure data in adjacent time periods in order to reflect the effect of any substitution that consumers make across item categories in response to changes in relative prices (Bureau of Labor Statistics 2003). Nevertheless, as the CPI is widely used for contract settlement and escalation clauses, it gives an indication of the revision sizes that may be tolerated.

[19] While we employ the Swedish data to learn about the potential magnitude of index revision associated with the OFHEO indexes, it should be noted that the data differ in two important ways. First, the Swedish data are arm's-length transactions only; there are no assessments from refinancing. Second, there is no limit on the price of dwellings we use in the analysis that might act like the conforming loan limitations used by the GSEs. To the extent that "starter homes" transact more frequently, our repeat-sales data are likely to be more heavily represented by those dwellings analogous to those that would be included in the OFHEO data. Moreover, if the arrival of dwelling sales into the data is explained by Stein's (1995) liquidity constraints, then our results may in fact understate the magnitude of revision. In this case, "winners" trade first, making the systematic downward revision found here an artifact of the late arrival of those dwellings that did not appreciate as much as the early arrivals.

[20] Note that this type of idiosyncratic price variation is likely to be far larger than aggregate index revision. Though true, it is not idiosyncratic risk that the homeowner insures

index initially reports no change in aggregate prices, this loss is attributed to idiosyncratic movements in the value of this particular home. Later, the arrival of new information that yields a downward revision to the index of 1% would imply that \$4,000 of the loss was due to aggregate price changes (for which the owner had purchased the insurance). This number would double to \$8,000 or more if the downward revision exceeded the 2% level that the repeat-sale indexes frequently do. By comparison, consider the impact of CPI-level revision on an insurance contract written in real terms: a change by 0.2% that is typical of CPI revisions would imply a loss of only \$800. This would be far more tolerable than the error associated with the repeat-sales index.[21]

In this example, the change in housing prices is mismeasured initially; subsequent information reveals that the estimate was too high. Consider the specifics of contract settlement. Contractual payments typically arise from the difference between two price indexes, $P_T - P_t$. In practice, the contract could be implemented as the difference between two initial estimates at the time of each transaction, $P(T, 1, T) - P(t, 1, t)$, as the difference between the two estimates at the time of the latter transaction, $P(T, 1, T) - P(t, 1, T)$, or some other variation on these themes.

We examine three types of contracts. The first employs the difference in initial estimates, $P(T, 1, T) - P(t, 1, t)$. In this case, the index estimate at the time of purchase and sale is set based on information available at t and at T with no subsequent revision based on new information allowed. The second approach measures price change based on two current indexes, $P(T, 1, T) - P(t, 1, T)$, making use of all available information at contract settlement to evaluate the change in aggregate prices. In our third approach to contract settlement, we recognize that revision is most significant in the quarters immediately following an initial estimate. The third approach delays index measurement in order to mitigate subsequent revision. We examine delaying measurement of aggregate prices in both the difference in the initial indexes and the difference in the current indexes. That is, we examine both $P(T, 1, T + d) - P(t, 1, t + d)$ and

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against. While the homeowner can exercise some control over maintenance and, to a lesser extent, the neighborhood, he or she is not able to protect against systematic movements in house prices at the metropolitan level. Revision at this level is the motivation for this example.

21 It is important to recognize that while a median index offers a more stable index, a quality-controlled index is required for these types of instruments. Consider an example of a metropolitan area in decline, precisely the application for which equity insurance was conceived. Here the composition of sold houses may shift toward higher-quality dwellings as higher-skilled, more mobile workers migrate to better employment opportunities. In the extreme, aggregate house prices may be declining, at the same time a median index would report rising house prices.

Table 6 ■ Contract settlement and settlement bias.

	Settlement Bias			
Contracting Approach	Average (%)	Min. (%)	Max. (%)	Std. Dev. (%)
Difference in				
Initial indexes	0.75	−2.74	5.02	1.44
Current indexes	1.26	−2.75	4.03	1.06
Initial indexes (delayed)[a]	0.20	−2.05	2.91	0.84
Current indexes (delayed)	0.62	−2.30	3.12	0.79

[a]Delay is eight quarters.

$P(T, 1, T + d) - P(t, 1, T + d)$. For our example, we delay measurement for eight quarters ($d = 8$).

The difference in initial indexes is surely the most straightforward to administer; it would involve no revision to the base during the course of the contract. It would also give a better measure of the true rate of index change if index revision were mainly systematic. Conversely, systematic revision would present a problem for contract settlement based on the difference between two current indexes. In such a case, aggregate prices at time of settlement would already account for (much of) the ultimate revision of the earlier purchase date index but none of the revision ultimately attributed to the sales date. Where revision is typically downward, this approach provides too little compensation to the holder of the insurance contract, as in the insurance example above. On the other hand, if revision were predominantly random, then basing the contract on the difference between the initial estimates would waste useful information; it would be preferable to base settlement on the current estimates.

To illustrate the implications of each of these settlement methods in the light of revision in repeat-sales indexes, we simulate the set of possible futures contracts possible during quarters 21–66.[22] For each contract $[P_T - P_t]$ where $T = 22, \ldots, 66, t = 21, \ldots, T - 1$, we calculate the estimated change in prices based on the four settlement methods described above using the standard repeat-sales approach. We then calculate the deviations between the settlements using the repeat-sales index and the benchmark Fisher ideal index. The "best" settlement approach is that which minimizes the deviation in contract settlement amounts.

Table 6 reports the results. The average settlement using current indexes is 1.26% higher than the average settlement using the benchmark index. Use

[22] Recall, that we define 21 quarters as the minimum sample period needed to ensure an adequate number of paired sales. We stop this exercise at quarter 66 in order to be able to impose the settlement delay, where required.

of initial indexes substantially mitigates the average bias, but the settlement bias exhibits substantially higher variation. The "best" method for contract settlement appears to be the use of the difference in delayed initial indexes. On average, this approach yields settlements only 0.20% different from settlements based on the benchmark index. Both delayed contracts exhibit lower variance in settlement bias, but they come at the cost of a delay of 2 years.

Conclusion

In contrast to the extensive literature that focuses on the static properties of housing price indexes, we focus on the dynamic characteristics of several commonly used indexes: those based on repeat-sale and hedonic models. In general, relatively little is known about the stability of these housing price indexes. We address several questions. What are the mechanics of revision? Are different indexes equally susceptible to revision? Is substantial revision common? And, is revision "large enough" to complicate the development of financial instruments based on aggregate housing prices? We focus centrally on the performance of the repeat-sales indexes as the sample period lengthens and as new paired-sales are added to the data. We do so because this methodology forms the basis for the only quality-controlled indexes systematically available for metropolitan areas and regions in many countries, including the United States. These price indexes are themselves inputs to a great deal of research, and they inform many of the discussions about price trends in owner-occupied housing in the United States.

We assess the importance of index revision in repeat-sales indexes against the benchmark of a chained Fisher index, which by definition is free of revision. The Fisher index employs all sales information, including characteristics of the transacted dwellings, in a flexible form that obviates the need to make the strong assumptions associated with the repeat-sale indexes. This is possible because the basis for the Fisher indexes is a series of cross-sectional regressions; housing characteristics and their implicit prices are allowed to vary over time. We also compare revision in the repeat-sales indexes against revision in an index constructed from a commonly used longitudinal hedonic model.

We find revision to be an inherent feature of repeat-sale indexes. The range of revision in the price level estimates is two to six times greater for the repeat-sales indexes relative to the longitudinal hedonic index. We find revision of the repeat-sale indexes to be asymmetric, with downward revision more prevalent than upward. We also find that revision in the repeat-sales indexes is primarily an "early" arrival problem. That is, most of the revision occurs in the first 10 quarterly estimates, and price estimates become more stable thereafter. This suggests systematic differences in the relative appreciation of those early entrants to the sample compared to those that arrive later. The hedonic-based index is not subject to this type of revision as it uses all sales data as they become available—no "new" information is added to data used to calculate prior hedonic regressions.

The second approach we take to assess the importance of index revision is examining its impact on a hypothetical market for home equity insurance and aggregate housing price futures. Given the difficulty in hedging the wealth represented by owner-occupied housing, these types of contracts may offer great benefits to homeowners and investors. However, both contracts require a settlement procedure that is based on an aggregate housing price index. Accuracy and stability are essential features for the functioning of these markets.

We find that levels of revision in the repeat-sales indexes are not inconsequential for the settlement process. We examine several modes of contract settlement in an effort to mitigate the impact of index revision with mixed results. The intuitive approach of settlement based on current indexes is problematic in the case of the repeat-sales indexes as revision of the initial price levels is both common and substantial. The "best" solution, one designed to reduce the instability of revision, requires lengthy delays in the final settlement of contracts. Neither approach appears conducive to the development of markets for housing futures or equity insurance. This suggests that the development of futures markets in housing prices would be better served by hedonic-based indexes, and that care must be taken when using a repeat-sales index as the only basis for the settlement of financial contracts.

We leave several issues for further research. First, we have not addressed the "cause" of revision in the repeat-sales indexes. The empirical regularity we document—systematic downward revision—may have its roots in nominal-loss aversion, positive price-volume correlation or some other reasons. Second, we have made no attempt to guide the design of specific financial instruments based on aggregate housing price indexes. We proceed in this article on the assumption that any metropolitan-level index would represent a new opportunity for diversification and would therefore be of some value. Of course, there are many issues, for example, the geographic definition of markets, that need close examination. However, independent of these and other challenges, the level of revision found in the repeat-sales indexes suggests that the OFHEO indexes may be inadequate for contract settlement.

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Table A1 ■ Mean characteristics, cross-sectional and longitudinal coefficients.

Housing Attribute	Average Characteristics[a]	Average Cross-Sectional Regression Coefficients[b]	Longitudinal Regression Coefficients[c]
Continuous variables			
Living area[d]	123	0.592	0.594
Square meters	(40)	(0.02)	(0.00)
Lot size[d]	999	0.090	0.088
Square meters	(2,299)	(0.01)	(0.00)
Distance to regional center[d]	19	−0.307	−0.311
Kilometers	(15)	(0.01)	(0.00)
Vintage	62	−0.002	−0.002
19xx	(18)	(0.00)	(0.00)
Dichotomous variables			
Tile bath	0.170	0.036 (0.02)	0.054 (0.00)
Sauna	0.221	0.044 (0.02)	0.043 (0.00)
Stone/brick	0.220	0.020 (0.01)	0.020 (0.00)
Single detached	0.617	0.079 (0.02)	0.082 (0.00)
Recroom	0.156	0.049 (0.02)	0.049 (0.00)
Fireplace	0.410	0.066 (0.01)	0.064 (0.00)
Laundry	0.752	0.029 (0.02)	0.040 (0.00)
One car garage	0.686	−0.004 (0.01)	−0.010 (0.00)
Two car garage	0.046	0.053 (0.03)	0.045 (0.00)
Waterfront	0.011	0.372 (0.06)	0.411 (0.01)
Insulation			
Walls only	0.166	0.048 (0.09)	0.056 (0.01)
Walls and windows	0.829	0.117 (0.09)	0.131 (0.01)
Kitchen			
Good	0.166	0.163 (0.01)	0.146 (0.01)
Excellent	0.825	0.168 (0.07)	0.172 (0.01)
Roof			
Good	0.707	0.040 (0.01)	0.039 (0.00)
Excellent	0.012	0.082 (0.06)	0.064 (0.01)
Price	976		
Thousand Swedish kronor	(648)		
R^2		0.675	0.806

[a]Standard deviations in parentheses.
[b]Standard deviation of estimates in parentheses.
[c]Standard errors of estimates in parentheses.
[d]Variables expressed in logarithms.