6

Repeat Sales Methods

The Basic Repeat Sales Model

6.1 The repeat sales method was initially proposed by Bailey, Muth and Nourse (1963). They saw their procedure as a generalization of the *chained matched model methodology* applied by the pioneers in the construction of real estate price indices like Wyngarden (1927) and Wenzlick (1952). The best-known repeat sales indices are the Standard and Poor's/Case-Shiller Home Price Indices in the US, which are computed for 20 cities (Standard and Poor's, 2009). The Federal Housing Finance Agency (FHFA) also computes a repeat sales index for the US,(1) using a slightly different approach. Residex and the UK Land Registry compute repeat sales indices for Australian cities and for the UK, respectively.(2)

6.2 As the name indicates, the method utilizes information on properties which have been sold more than once. Because it is a matched-properties type of method, controlling for period-to-period differences in the sample of properties is not required. However, because of the low incidence of resale units at times, it would not be very useful to compute a repeat sales RPPI using the standard matched model methodology and conventional index number formulae. Therefore, a stochastic model is postulated which "explains" the price changes of houses that have been sold repeatedly. This (dummy variable) regression model is then estimated on the pooled data (i.e., on the pooled price changes) across the sample period.

6.3 The only information required to estimate a standard repeat sales regression equation is price, sales date and address of the properties; therefore this method is much less data intensive than hedonic methods. Also, the repeat sales method controls by default for location at the finest level of detail (the address), something which hedonic regression methods are often unable to do with great precision.(3) One problem with the repeat sales method however is that a dwelling unit that is sold at two different points in time is not necessarily identical due to such factors as depreciation and renovations. Consequently, the longer the span of time between sales, the more questionable the constant-quality assumption underlying the repeat sales approach becomes.

(1) The FHFA was established in 2008 as a combination of the former US Office of Federal Housing Enterprise Oversight (OFHEO), who published the repeat sales index until then, and the Federal Housing Finance Board (FHFB).

(2) The Dutch Land Registry computed a repeat sales index for the Netherlands until 2007 when they changed over to a SPAR index, which is published jointly with Statistics Netherlands. For the SPAR method, see Chapter 7.

(3) However, the use of geospatial data to allow for spatial dependence in the hedonic equation could remedy the omitted locational variables problem; see Chapter 5 and Hill (2011) for more details.

6.4 The following stochastic model explaining the logarithm of the value (price) p_n^t for property n in period t can be found in the literature:

$$\ln p_n^t = P^t + H_n^t + \varepsilon_n^t \tag{6.1}$$

where P^t is a common term for all properties (the log of "price level" in some region or city), H_n^t is a Gaussian random walk that represents the drift in individual housing value over time, and ε_n^t is a random error term or white noise. Model (6.1) is often taken as the starting point for deriving the estimating repeat sales equation.

6.5 Another point of departure could be the constrained log-linear hedonic model (5.4), where the parameters β_k of the price-determining characteristics are constrained to be fixed over time. As "identical" properties are compared, there is a second restriction involved: the (amounts of the) characteristics of an individual property are also assumed fixed over time. Denoting the k'th characteristic for property n by z_{nk}, the constrained log-linear model now becomes

$$\ln p_n^t = \beta_0^t + \sum_{k=1}^{K} \beta_k z_{nk} + \varepsilon_n^t \tag{6.2}$$

6.6 A model for the logarithm of the change in value of property n between two periods, say s and t $(0 \le s < t \le T)$, is found by subtracting (6.2) for those periods. It follows that

$$\begin{aligned}\ln p_n^t - \ln p_n^s &= \ln(p_n^t / p_n^s) = (\beta_0^t - \beta_0^s) + (\varepsilon_n^t - \varepsilon_n^s) \\ &= \ln P^{st} + (\varepsilon_n^t - \varepsilon_n^s)\end{aligned} \tag{6.3}$$

Model (6.3) is essentially saying that, neglecting the error term $\varepsilon_n^t - \varepsilon_n^s$, the logarithm of the price change is the same for all properties, denoted by P^{st}.

6.7 Now suppose we have a sample of houses that have been sold more than once over the sample period $t = 0,...,T$ for which we have data on transaction prices, hence on their price changes. The (holding) period between subsequent sales will differ among those properties. However, given that in model (6.3) all individual property prices are expected to change at the same rate (excluding random disturbances), the repeat sales data can be pooled and the model estimated with the standard *repeat sales equation*

$$\ln(p_n^t / p_n^s) = \sum_{t=0}^{T} \gamma^t D_n^t + \mu_n^t \tag{6.4}$$

where D_n^t is a dummy variable with the value 1 in the period that the resale occurs, -1 in the period that the previous sale occurs, and 0 otherwise; μ_i^t is again an error term.(4) Under the so-called classical assumptions, in particular

(4) Multiple resales are treated as independent observations. As noted by Shiller (1991), this should not be overly problematic because there is no overlap between the holding periods of multiple resales.

that the errors have a zero mean and constant variance, equation (6.4) can be estimated by OLS regression. Some multicollinearity may be present in the data, but solutions to remedy this issue are limited if this is the case.

6.8 The repeat sales index going from period 0 to period t is obtained by exponentiating the corresponding regression coefficients $\hat{\gamma}^t$:

$$P_{RS}^{0t} = \exp(\hat{\gamma}^t) \qquad (6.5)$$

The simplicity and attractiveness of the standard repeat sales model resides on the fact that it only requires dummy variables; no characteristics data other than the location (address) are needed.([5]) This, coupled with the straightforward way to compute the repeat sales price index, might explain part of the popularity of the method in the real estate and housing literature.

6.9 Wang and Zorn (1997) derived an analytical expression for the repeat sales index. It appears to have a rather complex geometric structure. Thus, despite the fact that the idea of matching is easily understood, the method may be difficult to explain in detail. Moreover, as mentioned earlier, a geometric property price index may be undesirable as a target, especially for a stock RPPI. A solution could be the use of an arithmetic version of the repeat sales method, which was suggested by Shiller (1991). Standard and Poor's (Case-Shiller) Home Price Indices are based on the arithmetic repeat sales method (see Standard and Poor's, 2009).

Issues and Improvements to the Basic Model

6.10 In this section we will discuss a number of issues related to the repeat sales method and give a brief overview of extensions and improvements to the basic model that have been proposed in the literature.

Data Cleaning

6.11 In practical applications, properties that were resold very rapidly as well as those that were not resold for long periods, have sometimes been excluded from the repeat sales regressions as such transactions might be "atypical" and therefore bias the resulting price index. Clapp and Giacotto (1998) and Steele and Goy (1997) suggested eliminating very short holds from the dataset as these could be distressed sales arising from, for example, divorce or job loss, or speculative transactions. Jansen et al. (2008), using data from the Dutch Land Registry, found that houses resold within 12 months showed relatively strong price increases.

6.12 Reproducibility is one of the strengths of the repeat sales method. But if the procedure for excluding "atypical" observations differs from time to time, then reproducibility might be compromised.

Heteroskedasticity

6.13 Case and Shiller (1987, 1989) argued that changes in house prices include components whose variance increases with the interval of sales, so that the assumption of a constant variance of the errors is violated. They proposed a Weighted Least Squares (WLS) approach to correct for this type of heteroskedasticity. The weights are derived by regressing the squared residuals from the standard (OLS) repeat sales regression on an intercept and the time interval between sales. A modified version of their weighted repeat sales approach is used by the US Federal Housing Finance Agency to construct quarterly price indices for single-family homes. It can be argued that the error variance will be non-linear in time intervals (Calhoun, 1996), hence the squared OLS residuals are regressed on an intercept term, the time interval and the square of the time interval.

6.14 Some studies found ambiguous results for heteroskedasticity adjustment. Leishman, Watkins and Fraser (2002), using Scottish data, and Jansen *et al.* (2008), using Dutch data, applied the standard (OLS) repeat sales method and various weighted methods. Both studies concluded that the standard method was not inferior.

Sample Selection Bias

6.15 An important problem with repeat sales indices is the possibility of sample selection bias. The problem is that some types of houses may trade more frequently on the market than other types so that they will be over-represented in the repeat sales sample (with respect to the stock of houses or the sales during some period). When these types of houses exhibit different price changes, then the repeat sales index tends to be biased. For example, if low quality houses sell more frequently than high quality houses but high quality houses rise in price at a slower rate, a repeat sales index will tend to have an upward bias.

6.16 There are various reasons why the holding duration of properties can be unevenly distributed. Life-cycle theories on property holding periods suggest that less expensive houses are traded more frequently; when people move up the property ladder they will tend to move home less often. Lower transaction costs for less expensive properties, for instance due to lower stamp duties, may also

([5]) In some countries, such as the UK and the Netherlands, the Land Registry collects all transaction price data but only a very limited number of characteristics, like type of dwelling and of course address. It is therefore not surprising to see that in those countries repeat sales indices have been computed from Land Registry data. Note that the FHFE's repeat sales index in the US is based on data obtained from Fannie Mae and Freddie Mac for mortgages.

result in a higher turnover rate of less expensive homes. In addition, the Buy-to-Let market in some countries is more active in lower ranges of the price segments.

6.17 Quite a few studies addressed the issue of holding duration and sample selection bias in repeat sales price indices; see for example Case, Pollakowski and Wachter (1991) (1997), Cho (1996), Clapp, Giacotto and Tirtiroglu (1991), Gatzlaff and Haurin (1997), Hwang and Quigley (2004), and Steele and Goy (1997). Not all of these studies found strong evidence of sample selection bias. Clapp, Giacotto and Tirtiroglu (1991) did not find any systematic differences between the repeat sales sample and the full sample of transactions over the long run. They argued that arbitrage typically forces prices for the repeat sample to grow at the same rate as the prices for the full sample. Wallace and Meese (1997) concluded that their repeat sales sample was sufficiently representative of all sales during the sample period in question. However, the "sample" of all housing sales themselves may not be representative of the total housing stock.

6.18 Potential sample selection problems are inherent to the repeat sales method. To some extent they can be corrected for by stratifying the repeat sales sample. A problem in this context is that the sub-samples may become very small and produce volatile indices. Thus there may be an argument for smoothing the index numbers. Moreover, it can be argued that selling prices do not always exactly represent the market values of the properties, which can be viewed as a latent variable. There may be *transaction noise* involved that causes volatility of the measured price indices. Francke (2010) proposed a smoothing procedure that takes into account the fact that selling prices of repeatedly sold properties depend on the time interval between subsequent sales.

Inefficiency and Revision

6.19 The repeat sales method is often criticized for being inefficient since, by its nature, it is wasteful of data. This is true compared with the multi-period time dummy hedonic method: since only housing units that have sold more than once are used with the repeat sales method, the resulting data set is usually much smaller than the sample of transactions over a given period. On the other hand, the longer the sample period, the more data will be used by the repeat sales method (as more and more houses will have been resold). Thus, when the sample period grows and more data are added, the efficiency of the repeat sales method will increase faster than that of the hedonic approach. Besides, the repeat sales method is efficient in the sense that it does not use any other housing characteristics than the unit's address.

6.20 It is possible to augment a repeat sales dataset by using assessment data (also referred to as appraisals) as approximations for past or current values of houses that have not been resold during the sample period. Some of the data on which the repeat sales index would then be based would be pseudo rather than genuine repeat data. Most empirical studies on this issue are based on appraisals of dwellings that are about to be re-financed. It has been suggested that appraisals tend to over-estimate the actual selling price of the property. But the magnitude of the bias could depend on the purpose for which assessment information is collected. De Vries et al. (2009) investigated the reliability of the Dutch appraisal data, which are collected on the government's behalf for income and local tax purposes, and concluded that the quality was quite satisfactory and even improving over time. For more on the use of assessment information in a repeat sales index and the removal of appraisal bias, see for example Geltner (1996), Edelstein and Quan (2006), and Leventis (2006).

6.21 Similar to the multi-period time dummy method, the repeat sales method suffers from revision of previously computed indices: when additional repeat sales information becomes available, re-estimation will result in changes to the estimated coefficients and thus in the price indices inferred. There have been few empirical studies on this issue to date, e.g. Clapp and Giaccotto (1999), Butler, Chang and Crews Cutts (2005), and Clapham et al. (2006). The last authors found evidence to suggest that repeat-sales indices are relatively less stable than time dummy hedonic indices. Note that revisions may be related to sample selection bias; when the sample period is extended and the coefficients re-estimated, sample selection bias might decrease as the number of observed repeat sales increases.

Quality Change

6.22 Repeat sales indices are estimated on the premise that the quality of the individual properties (as measured by their characteristics) is unchanging over time. It is sometimes argued that in the aggregate, the value of renovations is approximately equal to the value of depreciation. For individual dwelling units, however, this cannot be true because over time, many units are demolished. One way to avoid this issue is to limit the sample of repeated sales observations to those units for which their quality is thought to be relatively constant from one sale period to the next. Case and Shiller (1989), for example, "extracted [.…] data on houses sold twice for which there was no apparent quality change". The problem is that the price changes inferred may not be indicative of the price changes for the full sample of repeated sales and may exacerbate the sample selection bias problem. (6)

(6) Meese and Wallace (1997) report that repeat sales units with changed characteristics tend to be larger and in worse condition than the average of units with single transactions.

6.23 If information on maintenance and renovation expenditures was available at the micro level, this could be used in the context of estimating a repeat sales (or hedonic) regression model for housing. In practice this kind of information is often lacking. Abraham and Schauman (1991) suggested adjusting the repeat sales index from aggregate data on renovation expenditures and make an adjustment for depreciation of the structures; see also Palmquist (1980) (1982). This approach to measuring net depreciation seems too crude and arbitrary to be suitable for the compilation of official statistics, however.

6.24 Shimizu, Nishimura and Watanabe (2010) recently developed a repeat sales method that takes net depreciation into account. Their method relies on an unknown taste parameter for which a guesstimate has to be made. While making an adjustment seems to be better than completely ignoring the (net) depreciation problem, making guesses might not be an attractive option for statistical agencies.

6.25 Shiller (1993a) developed a repeat sales method that accounts for possible changes in housing characteristics between first and second sales. The method involves including characteristics in a traditional repeat sales model. Clapp and Giaccotto (1998) advocated the use of assessed values at time of first and second sales as a parsimonious control for quality changes of the properties. Goetzmann and Spiegel (1997) suggested including a constant term in the repeat-sales regression to capture average quality change across all characteristics over the average holding period.

6.26 Case and Quigley (1991) were the first to advocate *hybrid models*. Hybrid models exploit all sales data by combining repeat sales and hedonic regressions and address not only the quality change problem but also sample selection bias and inefficiency problems. Case and Quigley (1991) and Quigley (1995) used samples of single-sale and repeat-sale properties to jointly estimate price indices using generalized least squares regression. Hill, Knight and Sirmans (1997) undertook a similar though more general exercise. Their model stacks two equations, a time dummy hedonic model (including age of the dwelling) and a repeat sales model, which are jointly estimated using maximum likelihood. They used a characteristics prices method to derive the price indices; see Chapter 5, equation (5.9). [7]

6.27 The rationale for hybrid methods is to try and combine the best features of the repeat sales and hedonic approaches. By combining both approaches, no data are discarded while repeat sales are still allowed to play a prominent role in the index construction methodology. However, we agree with Hill (2011) who has difficulty accepting that a repeat-sales price relative should be preferred to an (say double) imputation hedonic price relative. He notes that: “If repeat-sales price relatives are not deemed more reliable than double imputation price relatives, there is no reason to prefer hybrid methods to hedonic methods”. In the end, the complexity of hybrid models most likely makes them unsuitable for implementation by statistical agencies.

Main Advantages and Disadvantages

6.28 Below, the main advantages and disadvantages of the repeat sales method are listed. The main advantages are:

- The repeat sales method in its basic form needs no characteristics other than address of the properties that are transacted more than once over the sample period. Source data may be available from administrative records such as those from the Land Registry.
- Standard repeat sales regressions are easy to run and the price indices easy to construct.
- The repeat sales method is a matched-model type of method without any imputations. By construction, location is automatically controlled for.
- The results are essentially reproducible provided that the treatment of outliers and possible corrections for heteroskedasticity (as well as the choice between a geometric or arithmetic method) are clearly described.

6.29 The main disadvantages of the repeat sales method are:

- The method is inefficient in the sense that it does not use all of the available transaction prices; it uses only information on units that have sold more than once during the sample period.
- The basic version of the method ignores (net) depreciation of the dwelling unit. [8]
- There may be a sample selection bias problem in repeat sales data.
- The method cannot provide separate price indices for land and for structures.
- The method cannot be used if indices are required for very fine classifications of the type of property sold. In particular, if monthly property price indices are required, the method may fail due to a lack of market sales for smaller categories of property.
- In principle, estimates for past price change obtained by the repeat sales method should be updated as new transaction information becomes available. Thus the repeat

(7) Other papers on the use of hybrid models include Clapp and Giaccotto (1992), Knight, Dombrow and Sirmans (1995), Englund, Quigley and Redfearn (1998), and Hwang and Quigley (2004).

(8) As mentioned previously, there are ways to deal with this problem but they all appear to be too crude or too complex to be used for the compilation of official statistics.

sales property price index could be subject to perpetual revision.[9]

6.30 Haurin and Hendershott (1991) summarize the disadvantages of the repeat sales method as follows:

"The method is subject to many criticisms: (1) it does not separate house price change from depreciation, (2) renovation between sales is ignored, (3) the sample is not representative of the stock of housing, (4) attribute prices may change over time, and (5) a large number of sales are required before a reasonable repeat-sales sample is obtained." Donald R. Haurin and Patric H. Hendershott (1991; 260)

The fifth criticism in this quotation – the large number of sales required to obtain a reasonable data set with repeat sales– was not mentioned thus far. In the next section a basic OLS repeat sales index will be constructed using the data for the town of "A" that was used earlier in Chapters 4 and 5 to show the effect of having a very small repeat sales data set.

An Example Using Data for the Town of "A"

6.31 Recall that, after deleting houses which were older than 50 years at the time of sale and also deleting observations which had land areas greater than 1200 m^2 , we were left with 2289 sales in the 14 quarter sample period, starting in the first quarter of 2005 and ending in the second quarter of 2008. That is, we had an average of 163.5 single sales of detached dwelling units per quarter for the Dutch town of "A". A few houses were sold twice during the same quarter, and we deleted those short holds for the estimation of the repeat sales index (as they could be distressed sales). We ended up with only 85 repeat sales over the 14 quarter period. The OLS repeat sales index computed using this small data set, labeled as P_{RS} , is plotted in Figure 6.1 along with the chained stratified sample mean Fisher index, P_{FCH} , described in Chapter 4 and the hedonic imputation Fisher index, P_{HIF} , described in Chapter 5. These three price series are listed in Table 6.1.

(9) In practice, this is not necessarily a big problem. A similar problem occurs when monthly scanner data are used in a CPI; a moving window of observations can be used to construct a monthly CPI component where only the incremental inflation rate for the last month is used to update the index; see Ivancic, Diewert and Fox (2011) and de Haan and van der Grient (2011).

Figure 6.1. Repeat Sales Price Index, Chained Stratified Sample Fisher Price Index and Hedonic Imputation Fisher Price Index

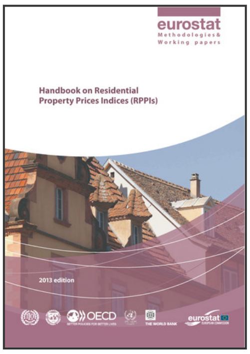
Source: Authors' calculations based on data from the Dutch Land Registry

Table 6.1. Repeat Sales Price Index, Chained Stratified Sample Mean Fisher Price Index and Hedonic Imputation Fisher Price Index

Quarter	P_{RS}	P_{FCH}	P_{HIF}
1	1.00000	1.00000	1.00000
2	1.00650	1.02396	1.04356
3	1.02802	1.07840	1.06746
4	1.02473	1.04081	1.03834
5	1.03995	1.04083	1.04794
6	1.04206	1.05754	1.07553
7	1.08663	1.07340	1.09460
8	1.07095	1.06706	1.06158
9	1.14474	1.08950	1.10174
10	1.15846	1.11476	1.10411
11	1.12709	1.12471	1.11430
12	1.13689	1.10483	1.10888
13	1.14903	1.10450	1.09824
14	1.12463	1.11189	1.11630

Source: Authors' calculations based on data from the Dutch Land Registry

6.32 Compared to the other two price indices, the repeat sales index turns out to be highly erratic during the second half of the sample period. In quarter 14, the repeat sales index shows a price decrease whereas the hedonic imputation and stratified sample means indices measure a price increase. Of course we cannot draw any definitive conclusions from this simple example, but it does confirm that repeat sales methods require a large number of observations to estimate price indices with acceptable precision.



From:

Handbook on Residential Property Price Indices

Access the complete publication at:
https://doi.org/10.1787/9789264197183-en

Please cite this chapter as:

OECD, *et al.* (2013), "Repeat Sales Methods", in *Handbook on Residential Property Price Indices*, Eurostat, Luxembourg.

DOI: https://doi.org/10.1787/9789264197183-8-en