The Role of Holding Periods in Repeat Sales Models

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Abstract

The paper shows that the average periodic return decreases with the holding period, both for residential real estate in the Netherlands and England & Wales, as well as for commercial real estate in the United States: The longer the holding period is, the lower on average the periodic return is.

The literature provides several reasons why the average periodic returns are higher for shorter holding periods. The first reason is the disposition effect: investors tend to sell more quickly a 'winner' and to hold onto a lower-performing property longer. The second reason is that there might be improvements just after purchasing the property.

The first implication of this finding is that the widely used repeat sales (RS) model is misspecified, because it does not differentiate between holding periods. The second implication is that systematic revisions in RS indices are due to the changing distribution of holding periods over time. This link has so far not been provided in the RS literature on index revision.

This paper proposes an adjustment to the RS model by including dummy variables for each holding period, apart from a baseline holding period to avoid perfect collinearity. The estimated price index represents the left-out holding period. This model solves the misspecification issue. Moreover, it is shown that (systematic) index revisions are much smaller in RS models including holding period dummy variables compared to a standard RS model.

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1 Introduction

It is well known that repeat sales (RS) models assume that property characteristics, and their corresponding impact on prices do not change over time. These assumptions are clearly violated by property improvements and depreciation. Although routine maintenance may partly offset depreciation, a RS index is therefore not constant quality.

This paper provides a different angle on RS models and focuses on the impact of the holding period. The paper shows that the average periodic return decreases with the holding period, both for residential real estate in the Netherlands and England & Wales, as well as for commercial real estate in the United States: The longer the holding period is, the lower on average the periodic return is.

The literature provides several reasons why the avferage periodic returns are higher for shorter holding periods. The first reason is the disposition effect: Because of behavioural bias investors and home-owners tend to sell more quickly a 'winner' and to hold onto a lower-performing property longer to avoid realizing losses (Genesove and Mayer, 2001; Bokhari and Geltner, 2011).

The second reason is that there might be improvements just after purchasing the property (Goetzmann and Spiegel, 1995). These improvements or capital expenditures will increase the property value. The quicker the subsequent sale is after the purchase, the smaller the depreciation on the improvement will be, so the larger the realized return. The investment in the property is typically not observed, and consequently cannot be corrected for.

Moreover, 'value-added' investors strategically purchase and sell commercial properties that need renovation, rehabilitation, and re-tenanting (Chinloy et al., 2013). The authors show that these 'value-added' returns are relatively high. Likewise, Steele and Goy (1997) and Depken et al. (2009) show that opportune buyers 'fix and flip' (improving and selling within one to two years after the purchase) residential properties, and experience above average returns. Depken et al. (2009) show that flips are older and smaller houses, and the number of flips is increasing relatively as the residential property market begins to takes off.

It can be concluded that observed holding periods might suffer from selection bias, because returns are only realized when a property is actually sold, and the selling decision potentially depends on the original purchase or subsequent sale price (Sagi, 2017), and the choice to make follow-on investments in the form of capital expenditures to improve the asset (Ambrose and Steiner, 2017).

The RS model has the property that new 'second' sales have their 'first' sale counterparts in the past, so when time proceeds more and more sales in the past are being used. Shiller (1993)[Chapter 8] emphasizes that there are substantial gains in efficiency of the estimated price index from adding new transactions. However, it is well documented that RS models

suffer from *systematic* index revision effects, see for example Gatzlaff and Haurin (1997), Clapp and Giaccotto (1999), and Clapham et al. (2006). The common finding is that each period when new sales arrive, the index values in previous periods are adjusted downwards. Clapp and Giaccotto (1999) show empirically that the magnitude of revisions are insensitive to large increases in sample size, and are more likely to be downward than upward. Clapham et al. (2006) find that hedonic indexes appear to be substantially more stable than RS indices and are not prone to the systematic downward revisions. Deng and Quigley (2008) find substantial revisions in quarterly RS indices for MSAs. The average revision is about 1.5% in absolute size, and in about 15% of the housing markets, the average absolute revision exceeds 2%. Index revisions are partly due to changes in geographical definitions of MSAs. Deng and Quigley find that revisions are not systematic, and are not predictable, either on the basis of lags and serial correlation or on the basis of simple macroeconomic factors. Jansen et al. (2008) find a small downward revision effect for the housing market in the Netherlands, after adding 1 additional year of transactions.

A commonly used approach to reduce the impact of revision is to omit flips, transactions with a holding period less than two years year, see for example Clapp and Giaccotto (1999). They find that excluding flips essentially removes the bias. Bourassa et al. (2013) argue that this might be a good strategy in markets with only a few flips, but not in markets where flips prevail; in these markets they prefer a repeat sales index to depart from the constant-quality assumption (by including flips) to more accurately reflect market conditions (Wang and Zorn, 1997). They propose a robust repeat sales estimator that is less sensitive to outliers (flips in case of 'normal' markets).

This paper provides empirical evidence that the average periodic return decreases with the holding period. The first implication is that the widely used RS model is misspecified, because it does not differentiate in the average periodic returns between holding periods.[1] It will be shown that the residuals from the RS model have a systematic (linear) relation with the holding period.

The second implication is that repeat sales suffer from systematic downward revisions. They would not occur when the repeat sales, the 'second sales' arriving each new period and their corresponding 'first' sales in previous periods, were random sub-samples of all sales in these periods. However, repeat sales are by definition not random with respect to the holding period. It is by construction that in a repeat sales model the holding period distribution is truncated: The maximum holding period is the sample length. When a new period of transactions is added to the sample, the maximum holding period increases by one. This

[1]The holding period only plays a role in the variance of the error term. Case and Shiller (1987, 1989) and Webb (1988) propose the variance term – apart from a constant term – to linear increase with the holding period. Abraham and Schauman (1991) propose a quadratic relation, whereas Hill et al. (1997) derive the variance term from a first order autoregressive process.

implies that in particular for short sample periods, the holding period frequency distribution will considerably change when new transactions arrive, and so the average periodic returns. This link has so far – apart from flips – not been provided in the literature on index revision in repeat sales models.

This paper uses three different data sources: 1) Residential property transactions in the Netherlands in the period 1993 – 2016, obtained from Land Registry; 2) Residential property transactions in England & Wales in the period 1995 – 2016, obtained from Land Registry[2]; 3) Commercial property transactions in the United States in the period 1997 – 2016, obtained from Real Capital Analytics.

It is shown that the average annual return decreases with the holding period by estimating repeat sales model on different sub-samples depending on the holding periods; holding periods of 1&2 years, 3&4 years, and so on. Next, it is empirically shown that there is no systematic index revision when the index is based on the the holding period sub-samples, whereas there is systematic index revision when the index is based on the total sample of repeat sales, providing proof for the argument that revision is due to the changing holding period distribution over time.

This paper proposes an adjustment to the repeat sales model by simply including dummy variables for each holding period, apart from a baseline holding period to avoid perfect collinearity.[3] By definition the average residual per holding period in this adjusted model is equal to zero. The estimated price index represents the left-out holding period. It is shown that these indices are very close to their sub-sample counterparts, and that systematic index revisions are much smaller compared to the standard repeat sales model.

The paper proceeds as follows. Section 2 describes the repeat sales model, and provides an adjustment for the length of the holding period. Section 3 gives a description of the transaction data that is used in the analysis. Section 4 gives the estimation results, and Section 5 concludes.

[2]Property sales in England & Wales that are sold for full market value and are lodged with us for registration. Contains HM Land Registry data © Crown copyright and database right 2017. This data is licensed under the Open Government Licence v3.0.

[3]This paper only considers annual indices. In case of higher frequency indices, the number of holding period dummy variables and corresponding coefficients is high, and a more parsimonious specification is more appropriate. The fixed holding period coefficients could be replaced by a stochastic process, for example a random walk. This is however outside the scope of this paper.

2 Methodology

2.1 Standard repeat sales model

The repeat sales model was introduced by Bailey et al. (1963). The sales price P for property i at time t can be expressed as

$$\ln P_{i,t} = \alpha_i + \mu_t + \varepsilon_{i,t},\ \varepsilon_{i,t} \sim N(0, \sigma^2),$$

where μ_t is the log price index at time t, $t = 0, \ldots T$, and α_i is a fixed effect for property i, $i = 1, \ldots N$. The sample of sale prices is split in two parts: one part containing 'single sales' – only one transaction for a property is available – and 'repeat sales' – two or more transactions of a property are available. Potential reasons for having 'only' one sale of a property are the following: Firstly, a previous sales is not observed: the sample does not have a long history, and secondly the property is recently constructed. The latter implies that repeat sales samples under-represent newer properties, which could potentially lead to biased price indices.

When two transactions of the same property are available, one can take the difference between the 'second' and the 'first' sale, cancelling out the property fixed effect, giving

$$r_{i,s,t} \equiv \ln P_{i,t} - \ln P_{i,s} = \mu_t - \mu_s + \varepsilon_{i,t} - \varepsilon_{i,s} = d_i \mu + \epsilon_{i,s,t}, \tag{1}$$

where s and t denote the time of the 'first' sale and 'second' sale, and $\mu = (\mu_1, \ldots, \mu_T)'$ are log price indices ($\mu_0 = 0$ for identification reason). d_i^{μ} is a selection vector for date of 'first' sale (-1) and 'second' sale (1) for property i, given by

$$d_i = \left(\underbrace{0 \cdots 0}_{1,\ldots,s-1} \quad \underbrace{-1}_{s} \quad \underbrace{0 \cdots 0}_{s+1,\ldots,t-1} \quad \underbrace{1}_{t} \quad \underbrace{0 \cdots 0}_{t+1,\ldots,T} \right).$$

The variance of the error term $\epsilon_{i,s,t}$ in Eq. (1) is $2\sigma^2$. Note that in case two (or more) pairs of the same property exist, the error terms of the first and second pair are correlated ($\mathrm{Cov}(\epsilon_{i,s,t}, \epsilon_{i,t,\tau}) = -\sigma^2$). For simplicity we will assume that these are uncorrelated, so basically assuming pair fixed effects instead of property fixed effects. An alternative assumption on the variance of the error term is that the variance is also dependent on the holding period: $\mathrm{Var}(\epsilon_{i,s,t}) = \alpha_0 + (t-s)\alpha_1 \left[+(t-s)^2\alpha_2\right]$, see for example Case and Shiller (1987, 1989), and Abraham and Schauman (1991).

A short hand notation of Eq. (1) is given by

$$r = D\mu + \epsilon.$$

The ordinary least squares (OLS) estimate of the log price index is given by

$$\hat{\mu} = (D'D)^{-1}D'r.$$

We can split the sample in pairs of properties having small and long holding periods. Let us define r_S and r_L as the subvectors containing all returns form short holding (for example ≤ 7 years) and long holding periods (> 7 years) respectively, and D_S and D_L likewise. The OLS estimate of the log price index based on the full sample can alternatively be expressed as a weighted average of the OLS estimate based on the observations with small holding periods ($\hat{\mu}_S = (D'_S D_S)^{-1} D'_S r_S$) and the OLS estimate based on the observations with long holding periods ($\hat{\mu}_L = (D'_L D_L)^{-1} D'_L r_L$):

$$\hat{\mu} = (I - A)\hat{\mu}_S + A\hat{\mu}_L,$$

where

$$A = (D'_S D_S + D'_L D_L)^{-1} D'_L D_L,$$

provided that both D_S and D_L have full column rank.

If there are systematic differences between the estimated price indices for short and long holding periods, then the repeat sales model specification is not correctly specified; both estimates should reinforce each other. I will test this empirically in Section 4 by applying the repeat sales model on different holding period samples.

2.2 Repeat sales model including holding period dummy variables

As a more parsimonious alternative to separate repeat sales model for the various sub-samples of holding periods, one can add dummy variables for each holding period, apart from a baseline holding period to avoid perfect collinearity with the linear term $t - s$, giving

$$r_{i,s,t} = d_i \mu^{(-k)} + e_i^{(-k)} \delta^{(-k)} + \epsilon_{i,s,t}, \tag{2}$$

where

$$e_i = \left(\underbrace{0 \cdots 0}_{hp_{min},\ldots,t-s-1} \quad \underbrace{1}_{t-s} \quad \underbrace{0 \cdots 0}_{t-s+1,\ldots,hp_{max}} \right),$$

hp_{min} and hp_{max} are the minimum and maximum holding period in the sample, and $(-k)$ denotes the omitted holding period $k \in \{hp_{\min}, \ldots, hp_{\max}\}$. This model can be estimated by ordinary least squares.

If the standard repeat sales model would be correctly specified, the estimated coefficients $\delta^{(-k)}$ should not be statistically significant different from zero (or from each other). I will

test this in Section 4.

Note that the residuals from Eq. (2) are identical for each left-out holding period, but the estimated price indices do substantially differ. It holds that

$$\begin{aligned}
\Delta\mu_t^{(-l)} &= \Delta\mu_t^{(-k)} + \frac{1}{l}\delta_l^{(-k)}, \\
\delta_j^{(-l)} &= \delta_j^{(-k)} - \left(1 + \frac{(j-m+1)}{l}\right)\delta_l^{(-k)}, j \neq k \\
\delta_k^{(-l)} &= -\left(1 + \frac{k-m+1}{l}\right)\delta_l^{(-k)},
\end{aligned}$$

so the difference in returns is a constant (not depending on t). This implies that the second moments of the returns (volatility and (auto)correlation) are identical, no matter which holding period has been left out.

An even more parsimonious alternative to separate repeat sales model for the various sub-samples of holding periods is to include just a constant, giving

$$r_{i,s,t} = \alpha + d_i\mu + \epsilon_{i,s,t}. \tag{3}$$

This specification has been suggested by Goetzmann and Spiegel (1995). The non-temporal component α captures fix-ups immediately after purchase. The index for holding period k is given by

$$\Delta\mu_t^{(k)} = \Delta\mu_t + \alpha/k. \tag{4}$$

In this paper I focus on annual returns in large repeat sales samples. In case of higher frequency returns and/or smaller samples, the holding period dummy variable approach will not be feasible – the number of parameters in relation to the number of observations is too high –, and the repeat sales model including a constant might be too rigid.

An alternative would be to replace the fixed holding period effects by a stochastic model, for example a random walk, but this outside the scope of this paper.

2.3 Revision

In this paper I will analyse potential revision effects in the various repeat sales models. Define $\mu_{t|\tau}$ as the log price index at time t using all transactions up to time τ, where $\tau = t, t+1, \ldots, T$. Revision of the index at time t using all transactions up to time τ_2 compared to all transactions up to time τ_1 is defined as $\omega_{t|\tau_1,\tau_2} = \mu_{t|\tau_2} - \mu_{t|\tau_1}$, where $\tau_2 > \tau_1$. I mainly focus on the average revision effect.

3 Data

The repeat sales models are applied on three different transaction datasets. The first one is obtained from the Dutch Land Registry and contains all sales in the owner-occupied residential sector in the Netherlands, starting from 1993 up to 2016. It includes both single and multifamily housing. The number of repeat sales is about one million. The total number of repeat sales is about 55% of all sales, single and repeat sales. The repeat sales are filtered. Following Clapp and Giaccotto (1999) all repeat sales having a holding period of 2 years or less are excluded from the sample. Repeat sales with an absolute annualized log return larger than 0.4 are excluded as well.

The second dataset (Price Paid Data) is obtained from HM Land Registry and contains all sales in the owner-occupied residential sector in England & Wales, starting from 1995 up to 2016. It includes both single and multifamily housing. The number of repeat sales is about eight million. The total number of repeat sales is about 38% of all sales, single and repeat sales. Repeat sales having a holding period of 2 years or less are excluded from the sample. Repeat sales with an absolute annualized log return larger than 0.4 are excluded as well.

The third dataset is obtained from Real Capital Analytics and contains sales in the commercial real estate (CRE) sector in the United States of America over the period 1992 up to 2016. The minimum holding period equals one year. Repeat sales with an absolute annualized log return larger than 0.4 are excluded from the sample.

Table 1 gives an overview of the repeat sales samples. The columns 'Pairs' gives the cumulative number of repeat sales pairs for the different years. Note that the number of pairs is low early in the US CRE sample. For that reason we initialize the index to 100 in 2000, both for housing in the Netherlands and England & Wales and commercial real estate in the United States. The columns 'Average Holding Period' gives the average holding period for all pairs with the second sale in the specified year. For housing in the Netherlands it grows from 4.7 years in 2000 to 10.7 in 2016, for housing in England & Wales it grows from 3.6 years in 2000 to 10.1 in 2016, and for commercial real estate in the United Staes it grows from 3.4 years in 2000 to 7.2 in 2016. The columns 'Cumulative Holding Period' gives the average holding period for all pairs up to the specified year. For housing in the Netherlands it grows from 4.2 years in 2000 to 7.4 in 2016, for housing in England & Wales it grows from 3.6 years in 2000 to 7.0 in 2016, and for commercial real estate in the United States it grows from 3.4 years in 2000 to 6.1 in 2016. So in all samples there is a significant change in the average holding period over time due to the censoring.

[Place Table 1 about here]

Figures 1 – 3 show the frequency distributions of the holding period in 2005, 2010, and 2016 for both for housing in the Netherlands and England & Wales, and commercial real estate in the United States. For housing in the Netherlands the mode of the distribution in 2005 is 4 years, and in 2016 it is 9 years. The mode is smaller than the average holding period in both years, respectively 6.2 and 10.7 years. For housing in England & Wales the picture is similar: The mode of the distribution in 2005 is 3 years, and in 2016 it is 9 years. The mode is smaller than the average holding period in both years, respectively 5.5 and 10.1 years. For commercial real estate in the United States the picture is a bit different. The mode of the distribution in 2005 is 2 years, and in 2016 it is 10 years. In 2005 the mode is much smaller than the average holding period of 4.4 years, in 2007 the mode is larger than the average holding period of 7.3 years.

[Place Figure 1 about here]

[Place Figure 2 about here]

[Place Figure 3 about here]

4 Estimation results

This section contains the estimation results for various repeat sales models. Section 4.1 provides price indices for different holding period sub-samples. Section 4.2 compares price indices from different repeat sales model specifications: The standard repeat sales model [Eq. (1)] for specific holding period sub-samples, the repeat sales model including holding period dummy variables [Eq. (2)], and the repeat sales model including a constant [Eq. (3)]. Finally, Section 4.3 examines the revision in the various repeat sales model specifications.

The indices are estimated on an annual basis. The base year for the index is 2000. Index revision statistics are based on the index values starting from 2005.

4.1 Holding period sub-samples

First of all, the standard repeat sales, given by Eq. (1), is estimated on the full samples. Figure 4 provides the average log residuals per holding period, both for housing in the Netherlands, and England & Wales, and commercial real estate in the United States. The results clearly show that the standard repeat sales model is misspecified.

For housing in the Netherlands there is a linear relationship between average residual and holding period; the higher the holding period, the lower the average residual. When the holding period is 10 years, the average residual is zero. For housing in the England & Wales

the average residual is linearly declining, up to a holding period of 10 years; after 10 years it is almost a flat line. When the holding period is 8 years, the average residual is zero. The negative relation between holding period and average residual also holds for commercial real estate in the United States, and is even steeper, however less clear for the longer holding periods because of the low number of pairs. When the holding period is 8 years, the average residual is zero.

[Place Figure 4 about here]

Next, the standard repeat sales model, given by Eq. (1), is estimated on different sub-samples defined by holding periods. Table 2 provides some statistics on the annual returns for different sub-samples of holding periods, and Figures 5 – 7 give the estimated price indices. For housing in the Netherlands the difference in the average annual return for holding periods 1&2 versus 11&12 is 2.6% points, for England & Wales it is 3.2%, and for commercial real estate in the US it is even 7.1%. Note that the volatility increases with the holding period, but to a lesser extent. The results clearly indicate that the standard repeat sales model is misspecified because it does not differentiate between holding periods.

[Place Table 2 about here]

[Place Figure 5 about here]

[Place Figure 6 about here]

[Place Figure 7 about here]

4.2 Comparison of indices for different repeat sales model specifications

This section compares the price indices from different repeat sales models:

- Standard repeat sales model [Eq. (1)] estimated on the sub-sample of holding period 5&6 (and 7&8), indicated by the dashed lines in Figures 8 – 10 with label 5&6 (7&8);
- Repeat sales model with holding period dummy variables [Eq. (2)] with left-out holding period 5 (7), indicated by the solid lines with label HP(-5) (HP(-7));
- Repeat sales model with constant [Eq. (3)] for holding period 5 (7), indicated by dotted lines with label CST5 (CST7).

For housing in the Netherlands it holds that the three repeat sales indices for the same holding periods are very similar; the indices from the repeat sales model with holding period

dummy variables almost coincide with the index from the repeat sales model with a constant, both for the 5 and 7 years holding period. The standard repeat sales index estimated on the 5&6 (7&8) years holding period slightly deviate from their counterparts, but the difference is small. Note that it is impossible to estimate the standard repeat sales model on only one holding period (identification issue). The same conclusion holds for the indices for housing in England & Wales.

The results for commercial real estate in the US are less clear. The indices from the repeat sales model with holding period dummy variables almost coincide with the index from the repeat sales model with a constant, for the 7 years holding period. The standard repeat sales index estimated on the sub-sample of 7&8 deviates from these indices, mainly because of the relatively low number of pairs included in the estimation (around 7,300). The indices for the 5 years holding period show much variation.

[Place Figure 8 about here]

[Place Figure 9 about here]

[Place Figure 10 about here]

4.3 Revisions

This section compares revisions in the different repeat sales models. The Tables 3 – 5 provide log indices derived from the standard RS model, starting from 2005 (right part of the table) up to 2016 (left part of the table), for housing in the Netherlands (Table 3), and England & Wales (Table 4), and commercial real estate in the United States (Table 5). The upper panels of the tables contain the log indices based on all holding periods (3 years or more for housing, 1 year or more for commercial real estate), and the lower panels of the table contain the log indices based on the sub-samples of holding periods 3&4 and 5&6 years.

It is clear that the indices based on all holding periods suffer from systematic downward revisions, despite the fact that the estimates are based on large numbers of pairs (for England & Wales about 6.5 million in the sample up to 2016). In the Netherlands the systematic revision of the log index level in 2009 is -0.021 (0.388 based on all pairs up to 2009 and 0.367 based on all pairs up to 2016). In England & Wales the systematic revision of the log index level in 2010 is -0.020 (0.751 based on all pairs up to 2010 and 0.731 based on all pairs up to 2016). Note that the systematic revision for commercial real estate in the United States is much larger: It is -0.085 in 2008 (0.441 based on all pairs up to 2008 and 0.356 based on all pairs up to 2016). This is partly due to the relative low number of RS pairs, about 43,000.

Note that the revision for the indices based on the sub-samples of holding periods is not systematic: It is random and much smaller than for the sample including all holding periods.

It can be concluded that index revision in the standard RS model is largely due to the changing distribution of holding periods over time. Keeping the holding period constant – like in the lower panels – prevents from systematic index revisions over time.

The Tables 6 – 8 show log index revision statistics for housing in the Netherlands, and England & Wales, and commercial real estate in the United States. The Tables provide statistics for $\mu_{t|\tau_2}$ - $\mu_{t|\tau_1}$, $\tau_2 > \tau_1 > t$, $t = 2005, \ldots, 2015$: Average (of the absolute value), median of the absolute value, minimum and maximum, and standard deviation, all $\times 100$. Moreover, they show the percentages that the absolute revision exceeds a threshold.

The different rows contain the various RS models: 'Standard' denotes the standard RS model given by Eq. (1), HP $(-k)$ the RS models with holding period dummy variables with left-out holding period k, given by Eq. (2), and Cst $(-k)$ denotes the RS model including a constant given by Eq. (3) and the index is calculated from Eq. (4). Note that each variant of the RS model with holding period dummy variables has identical residuals, however different indices. The same holds for the RS model with a constant.

In the standard RS model the average revision is about -0.62% for housing in the Netherlands and -0.44% in England & Wales. The revision is larger than 1% for 21% (17%) of the cases in the Netherlands (England & Wales). The average revision is about 2.24% for commercial real estate in the United States, and the revision is larger than 4% for 20% of the cases.

The RS models including holding period dummy variables constant have much smaller revisions, depending on the left-out holding period. For housing in the Netherlands (England & Wales) the left-out holding period of 6 (6) years has the lowest average revision: It is about 8 (18) times as small as in the standard RS model. For commercial real estate in the United States the left-out holding period of 5 years has the lowest average revision: It is about 13 times as small as in the standard RS model.

Note that these left-out holding periods are close to the average holding period, ranging from 5.3 in 2005 to 7.4 in 2016 for housing in the Netherlands, ranging from 4.9 in 2005 to 7.0 in 2016 for housing in England & Wales, and ranging from 4.3 in 2005 to 6.1 in 2016 for commercial real estate in the United States, see Table 1.

Similar results are obtained for the RS including a constant, where the index for holding period k is obtained by Eq. (4).

Not only the estimated indices are updated over time, also the coefficients for the holding period dummy variables (Eq. (2)) and the constant (Eq. (3)) are updated. The Tables 9 – 11 show that these coefficients suffer from systematic revision effects as well. However, the coefficient for the constant divided by the average holding period in the sample, is relatively

stable over time, see Table 11, in specific for housing.

It follows from the results in Tables 6 – 8 that, although the coefficients of the holding period dummy variables and the constant systematically revise over time, the revision in indices is less compared to the standard RS model.

[Place Table 3 about here]

[Place Table 4 about here]

[Place Table 5 about here]

[Place Table 6 about here]

[Place Table 7 about here]

[Place Table 8 about here]

4.4 Sensitivity Analysis

- Weighted Least Squares: variance in repeat sales model depends on holding period;
- Cheap versus expensive homes (based on the percentiles of the first sales price);
- Single versus multifamily homes.

Results have to be included in the paper. The main findings still hold.

5 Conclusion

In this paper it has been demonstrated that repeat sales indices based on different holding period sub-samples vary substantially. There appears to be a systematic pattern that shorter holding periods have higher periodic index returns. This feature has so far been neglected in repeat sales applications: the standard repeat sales model assumes holding period independent index returns and is therefore misspecified. The misspecification is empirically demonstrated by a systematic negative relation between the average residuals per holding period and the holding period. In the repeat sales literature the holding period only plays a role in the variance of the error term in the weighted least squares repeat sales model, and this effect is only secondary (efficiency of ordinary least squares estimates).

It is by construction that in a repeat sales model the frequency distribution of holding periods is truncated: The maximum holding period is the sample length. When a new period of transactions is added to the sample, the maximum holding period will increase

by one period. This implies that – in particular for short sample periods – the frequency distribution will considerably change.

The combination of the changing holding period distribution over time and the dependence of the index returns on the holding periods causes the frequently observed systematic downward revision effects in repeat sales price indices. Specifically, in short samples the frequency distribution will change, and so the expected revisions will be big.

The repeat sales model including holding period dummy variables solves the misspecification issue. By definition the average residuals per holding period are equal to zero. In order to avoid perfect collinearity one holding period dummy variable has to be left-out. The index represents the index of the left-out holding period, and in the empirical analysis it coincides with the index from the standard repeat sales model estimated on the similar sub-sample of holding periods. The repeat sales model including holding period dummy variables also reduces considerably the size of the revisions, depending on the left-out holding period dummy variable.

The repeat sales model with a constant (adjusted for the holding period) gives in large samples a very good approximation of the results from the repeat sales model including holding period dummy variables: the estimated indices virtually coincide. And this model is much more parsimonious, so applicable in smaller samples and/or for higher frequency indices. An intermediate solution would be to replace the fixed holding period effects by a flexible stochastic function, for example a random walk. This gives flexibility without introducing a large number of unknown parameters.

The fact that repeat sales indices depend on the holding period frequency distribution raises the question which index to publish. In the standard repeat sales index the holding period frequency distribution changes over time because of truncation, so the index is not constant holding period. Constant holding period indices can easily be constructed by having a weighted average of the holding period specific indices (from one of the repeat sales models), where the weights are fixed in time. However, this approach neglects the fact that – apart from truncation – a time varying holding period frequency distribution might reflect changing market conditions.

A related topic is how long a repeat sales sample has to be such that a change in the holding period frequency distribution has a negligible effect on the repeat sales index. What can be learnt from the current application is that it takes a long time for a repeat sales database to mature.

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A Figures

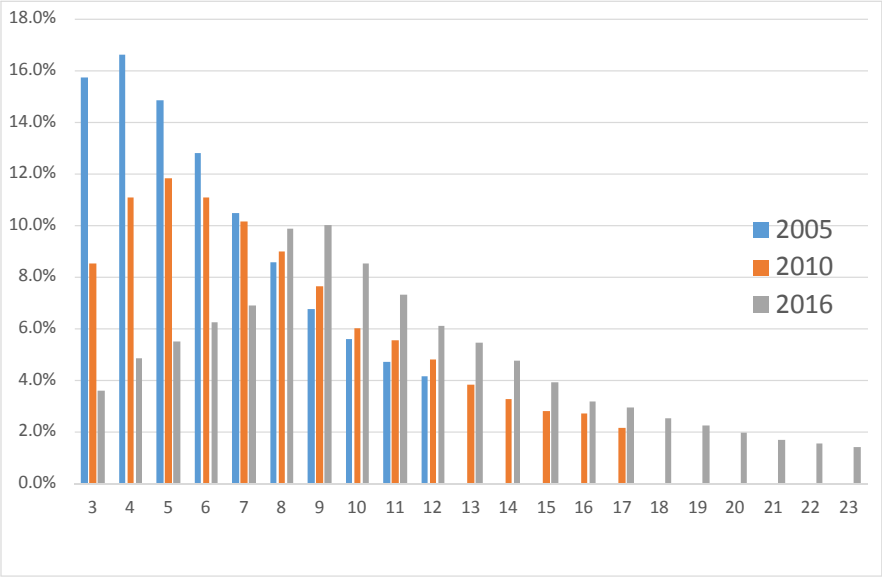

Figure 1: Holding period distribution for housing in the Netherlands in 2005, 2010, and 2016.

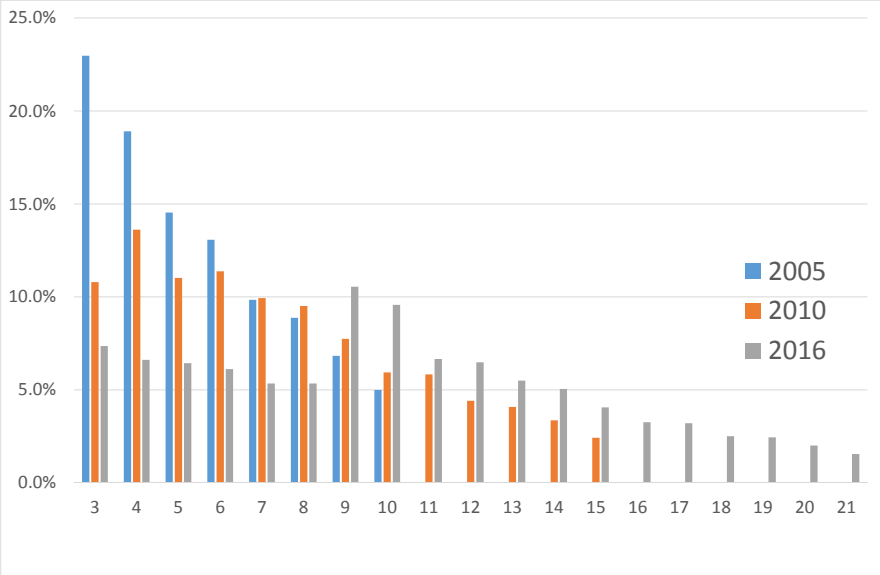

Figure 2: Holding period distribution for housing in England & Wales in 2005, 2010, and 2016.

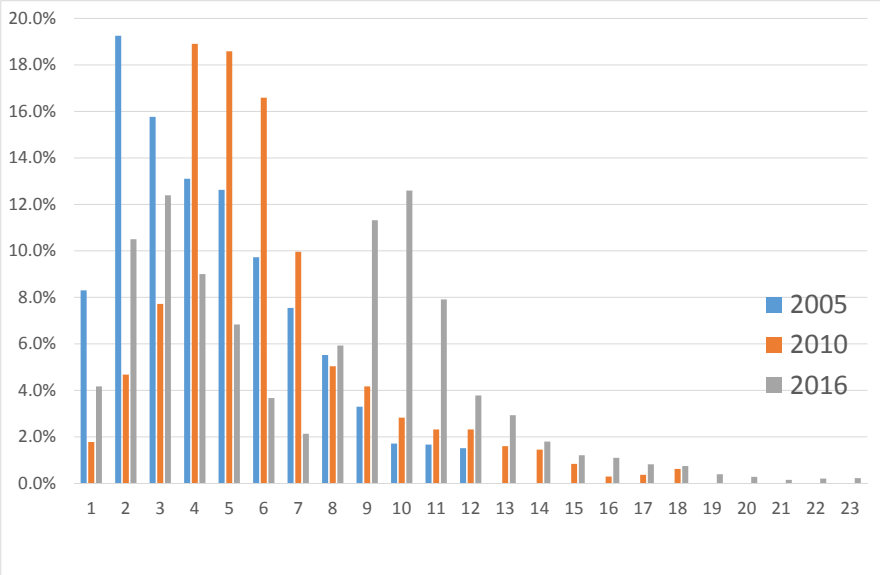

Figure 3: Holding period distribution for CRE in the US in 2005, 2010, and 2016.

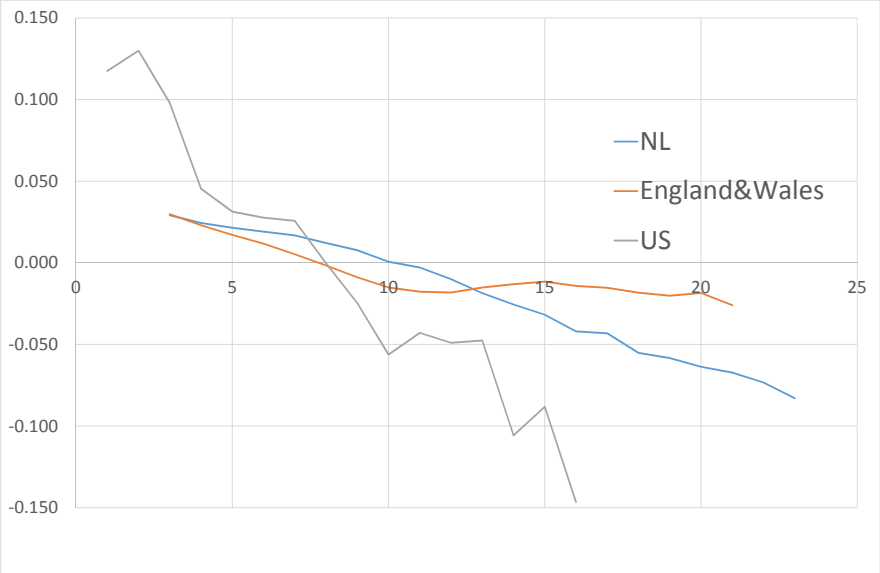

Figure 4: Average residuals (in logs) per holding period for the standard repeat sales model for housing in the Netherlands, England & Wales, and commercial real estate in the US.

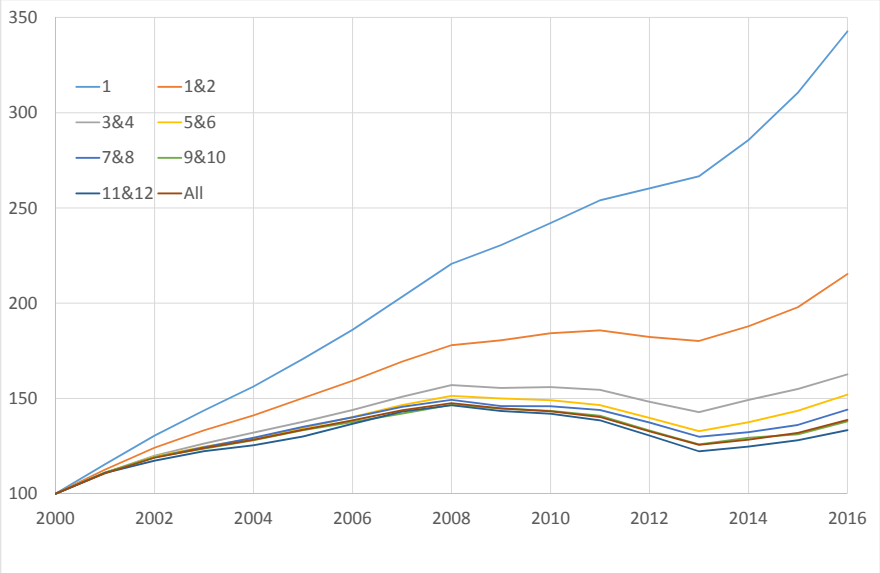

Figure 5: Indices for different holding period sub-samples for housing in the Netherlands.

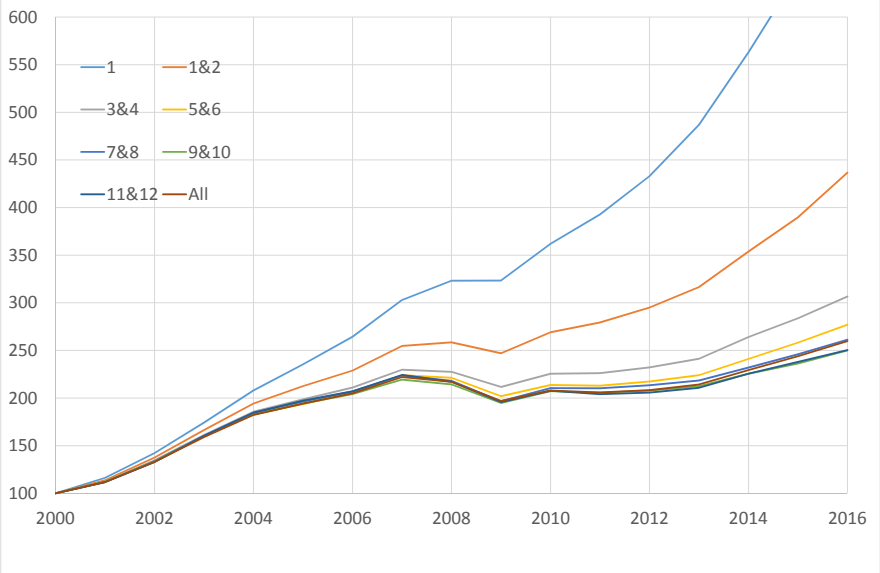

Figure 6: Indices for different holding period sub-samples for housing in England & Wales.

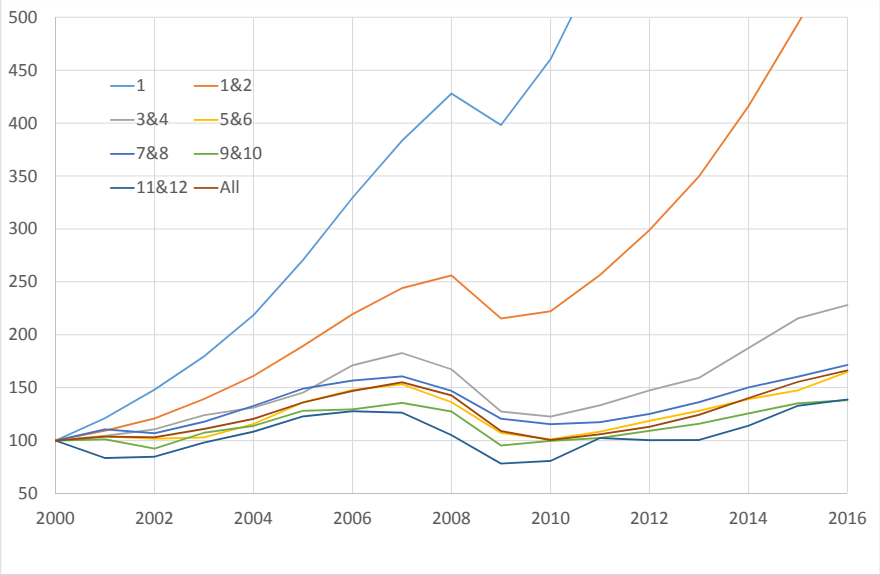

Figure 7: Indices for different holding period sub-samples for CRE in the US.

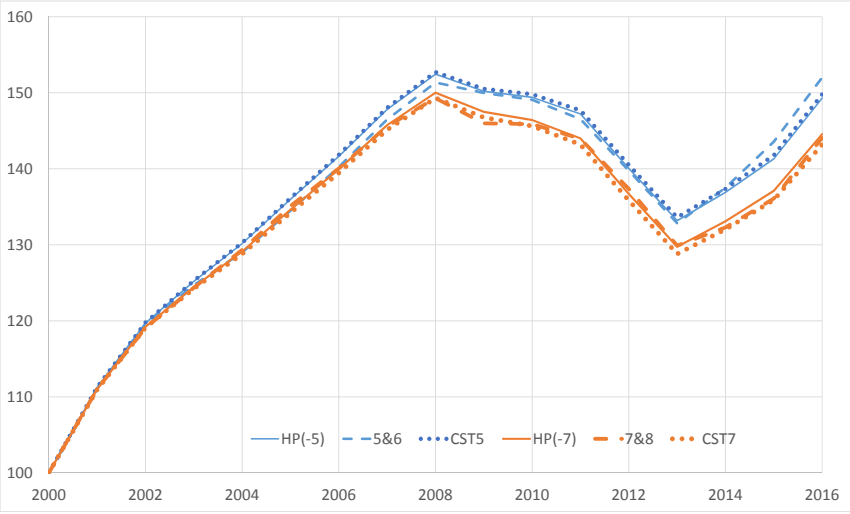

Figure 8: Comparison of indices from various repeat sales models for housing in the Netherlands.

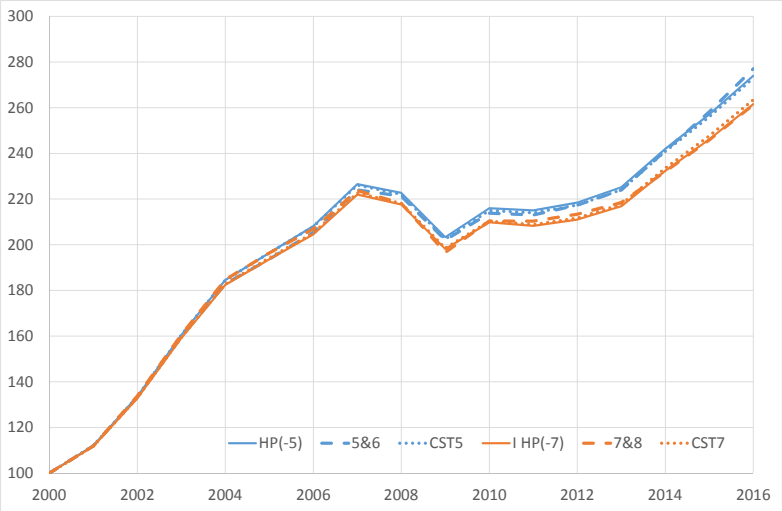

Figure 9: Comparison of indices from various repeat sales models for housing in England & Wales.

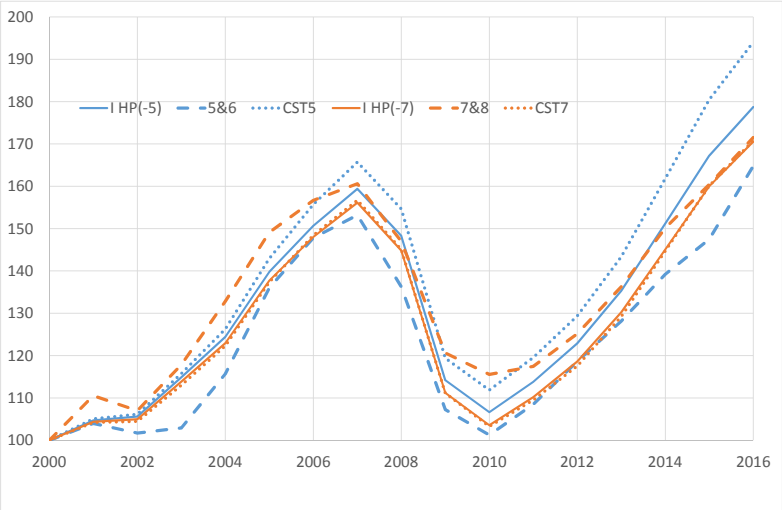

Figure 10: Comparison of indices from various repeat sales models for commercial real estate in the US.

B Tables

Table 1: Average (cumulative) holding period per year of second sale.

	Housing NL			Housing England&Wales			Commercial US		
Year	Pairs	Avg.	Cum.	Pairs	Avg.	Cum.	Pairs	Avg.	Cum.
2000	112,087	4.7	4.2	357,386	3.8	3.6	187	3.4	3.3
2001	155,413	5.1	4.4	622,848	4.3	3.9	493	3.8	3.6
2002	204,883	5.4	4.7	966,720	4.6	4.1	915	4.1	3.8
2003	256,691	5.7	4.9	1,311,085	4.9	4.3	1,584	4.2	4.0
2004	312,654	6.0	5.1	1,695,072	5.2	4.5	2,876	4.3	4.2
2005	378,410	6.2	5.3	2,061,490	5.5	4.7	5,395	4.5	4.3
2006	449,497	6.6	5.5	2,577,031	5.8	4.9	8,045	4.6	4.4
2007	518,442	7.0	5.7	3,094,301	6.0	5.1	11,271	4.5	4.4
2008	584,259	7.3	5.9	3,340,193	6.5	5.2	13,275	5.2	4.5
2009	629,541	7.6	6.0	3,602,428	7.1	5.3	14,391	5.4	4.6
2010	674,653	8.0	6.1	3,918,350	7.4	5.5	16,210	5.6	4.7
2011	718,110	8.4	6.3	4,229,420	8.0	5.7	18,971	6.1	4.9
2012	760,085	9.0	6.4	4,553,527	8.5	5.9	22,511	6.5	5.2
2013	798,024	9.5	6.6	4,960,701	8.9	6.1	26,636	7.0	5.4
2014	854,026	9.9	6.8	5,473,993	9.3	6.4	31,693	7.1	5.7
2015	924,892	10.4	7.1	5,979,623	9.8	6.7	37,322	7.3	5.9
2016	1,017,064	10.7	7.4	6,480,620	10.1	7.0	42,723	7.3	6.1

Table 2: Annual returns for different holding periods.

	Housing				Commercial	
	Netherlands 1993 - 2016		England&Wales 1995 - 2016		US 1997 - 2016	
Holding Period	Avg	Std	Avg	Std	Avg	Std
1	0.099	0.045	0.124	0.048	0.159	0.071
1&2	0.072	0.050	0.095	0.056	0.117	0.084
3&4	0.055	0.053	0.074	0.062	0.061	0.102
5&6	0.051	0.054	0.068	0.064	0.046	0.098
7&8	0.049	0.055	0.064	0.067	0.033	0.080
9&10	0.047	0.057	0.063	0.067	0.031	0.098
11&12	0.046	0.058	0.063	0.069	0.046	0.145
All	0.047	0.056	0.065	0.066	0.038	0.094
Pairs	1,180,709		8,264,012		42,723	

Table 3: Revision in standard repeat sales model for housing in the Netherlands.

Year	I2016	I2015	I2014	I2013	I2012	I2011	I2010	I2009	I2008	I2007	I2006	I2005	Last - First
	Holding periods > 2 years												
2005	0.288	0.289	0.290	0.291	0.292	0.294	0.295	0.297	0.299	0.302	0.301	0.302	-0.014
2006	0.324	0.326	0.328	0.329	0.331	0.332	0.334	0.336	0.338	0.338	0.338		-0.013
2007	0.361	0.364	0.366	0.368	0.370	0.372	0.374	0.377	0.377	0.377			-0.015
2008	0.387	0.391	0.394	0.397	0.399	0.402	0.404	0.404	0.405				-0.018
2009	0.367	0.372	0.377	0.381	0.384	0.386	0.387	0.388					-0.021
2010	0.357	0.363	0.369	0.373	0.376	0.377	0.378						-0.020
2011	0.338	0.345	0.350	0.355	0.355	0.356							-0.019
2012	0.282	0.288	0.292	0.294	0.295								-0.013
2013	0.227	0.232	0.233	0.234									-0.008
2014	0.250	0.252	0.254										-0.004
2015	0.275	0.277											-0.002
	3&4 years holding periods												
2005	0.321	0.320	0.321	0.321	0.320	0.320	0.321	0.320	0.319	0.323	0.323	0.319	0.001
2006	0.364	0.364	0.364	0.364	0.364	0.365	0.365	0.363	0.364	0.365	0.364		0.000
2007	0.412	0.412	0.411	0.412	0.412	0.412	0.411	0.413	0.413	0.412			-0.001
2008	0.451	0.450	0.451	0.451	0.451	0.449	0.451	0.451	0.450				0.001
2009	0.441	0.442	0.442	0.442	0.440	0.443	0.443	0.442					-0.001
2010	0.445	0.446	0.445	0.443	0.446	0.447	0.446						-0.002
2011	0.435	0.435	0.434	0.437	0.437	0.436							-0.001
2012	0.394	0.391	0.392	0.392	0.391								0.003
2013	0.356	0.363	0.363	0.362									-0.005
2014	0.400	0.401	0.400										0.000
2015	0.438	0.436											0.002
	5&6 years holding periods												
2005	0.296	0.296	0.296	0.297	0.297	0.297	0.296	0.297	0.297	0.298	0.298	0.299	-0.002
2006	0.338	0.339	0.339	0.338	0.338	0.338	0.339	0.338	0.338	0.337	0.337		0.001
2007	0.382	0.382	0.381	0.379	0.379	0.381	0.381	0.381	0.379	0.378			0.004
2008	0.414	0.413	0.411	0.409	0.409	0.410	0.410	0.409	0.407				0.007
2009	0.405	0.403	0.399	0.403	0.403	0.404	0.403	0.402					0.004
2010	0.399	0.394	0.398	0.399	0.399	0.399	0.398						0.001
2011	0.382	0.387	0.387	0.387	0.387	0.387							-0.005
2012	0.335	0.335	0.335	0.334	0.334								0.001
2013	0.284	0.283	0.282	0.280									0.004
2014	0.318	0.317	0.314										0.004
2015	0.362	0.358											0.003

Table 4: Revision in standard repeat sales model for housing in England & Wales.

Year	I2016	I2015	I2014	I2013	I2012	I2011	I2010	I2009	I2008	I2007	I2006	I2005	Last - First
	Holding periods > 2 years												
2005	0.661	0.660	0.659	0.659	0.659	0.660	0.661	0.663	0.665	0.667	0.666	0.665	-0.004
2006	0.714	0.713	0.713	0.713	0.713	0.715	0.716	0.719	0.721	0.721	0.721		-0.007
2007	0.794	0.794	0.795	0.796	0.799	0.801	0.803	0.807	0.807	0.807			-0.013
2008	0.771	0.772	0.773	0.776	0.779	0.782	0.787	0.787	0.788				-0.017
2009	0.674	0.676	0.678	0.681	0.685	0.689	0.689	0.690					-0.016
2010	0.731	0.734	0.738	0.744	0.749	0.750	0.751						-0.020
2011	0.721	0.725	0.730	0.737	0.737	0.738							-0.017
2012	0.733	0.738	0.745	0.745	0.746								-0.013
2013	0.761	0.767	0.767	0.768									-0.007
2014	0.830	0.831	0.832										-0.001
2015	0.886	0.886											-0.001
	3&4 years holding periods												
2005	0.686	0.686	0.687	0.687	0.686	0.686	0.687	0.686	0.685	0.687	0.687	0.682	0.005
2006	0.746	0.747	0.747	0.746	0.746	0.747	0.747	0.745	0.746	0.747	0.746		0.001
2007	0.832	0.832	0.831	0.831	0.832	0.832	0.830	0.832	0.832	0.832			0.000
2008	0.822	0.821	0.822	0.823	0.822	0.820	0.825	0.825	0.824				-0.002
2009	0.749	0.750	0.752	0.752	0.746	0.749	0.749	0.748					0.001
2010	0.813	0.815	0.814	0.811	0.817	0.817	0.816						-0.003
2011	0.816	0.815	0.810	0.815	0.816	0.815							0.001
2012	0.843	0.837	0.846	0.846	0.843								0.000
2013	0.881	0.887	0.888	0.886									-0.005
2014	0.971	0.971	0.969										0.002
2015	1.043	1.039											0.003
	5&6 years holding periods												
2005	0.661	0.660	0.661	0.662	0.662	0.663	0.661	0.661	0.662	0.663	0.663	0.663	-0.002
2006	0.720	0.720	0.720	0.719	0.719	0.718	0.720	0.719	0.719	0.718	0.719		0.001
2007	0.806	0.806	0.805	0.804	0.802	0.808	0.808	0.807	0.806	0.805			0.002
2008	0.794	0.793	0.790	0.788	0.794	0.797	0.797	0.795	0.793				0.001
2009	0.703	0.701	0.695	0.698	0.700	0.703	0.702	0.698					0.005
2010	0.760	0.756	0.761	0.762	0.763	0.764	0.762						-0.003
2011	0.756	0.759	0.759	0.759	0.759	0.759							-0.002
2012	0.776	0.777	0.775	0.775	0.774								0.002
2013	0.806	0.806	0.804	0.802									0.004
2014	0.880	0.879	0.874										0.006
2015	0.948	0.946											0.003

Table 5: Revision in standard repeat sales model for commercial real estate in the US.

Year	I2016	I2015	I2014	I2013	I2012	I2011	I2010	I2009	I2008	I2007	I2006	I2005	Last-First
	Holding periods > 2 years												
2005	0.308	0.311	0.303	0.299	0.299	0.301	0.301	0.303	0.307	0.315	0.326	0.337	-0.030
2006	0.385	0.387	0.387	0.388	0.393	0.400	0.402	0.403	0.406	0.418	0.422		-0.037
2007	0.439	0.444	0.443	0.450	0.455	0.465	0.468	0.479	0.490	0.498			-0.059
2008	0.356	0.364	0.366	0.373	0.389	0.405	0.421	0.435	0.441				-0.085
2009	0.086	0.090	0.087	0.087	0.093	0.110	0.129	0.137					-0.051
2010	0.006	0.011	0.005	0.010	0.025	0.047	0.053						-0.047
2011	0.058	0.064	0.071	0.085	0.103	0.112							-0.055
2012	0.122	0.132	0.145	0.162	0.171								-0.048
2013	0.218	0.236	0.250	0.257									-0.038
2014	0.338	0.358	0.363										-0.026
2015	0.441	0.453											-0.012
	3&4 years holding periods												
2005	0.374	0.373	0.379	0.378	0.373	0.374	0.392	0.378	0.372	0.399	0.389	0.321	0.053
2006	0.537	0.542	0.543	0.537	0.537	0.542	0.541	0.504	0.511	0.522	0.487		0.050
2007	0.603	0.604	0.598	0.600	0.603	0.603	0.586	0.606	0.606	0.605			-0.002
2008	0.515	0.508	0.517	0.520	0.516	0.510	0.547	0.542	0.538				-0.023
2009	0.242	0.248	0.257	0.253	0.234	0.249	0.256	0.229					0.013
2010	0.205	0.214	0.211	0.197	0.210	0.212	0.204						0.001
2011	0.287	0.283	0.268	0.282	0.283	0.281							0.006
2012	0.388	0.367	0.404	0.405	0.397								-0.010
2013	0.466	0.504	0.505	0.495									-0.029
2014	0.628	0.629	0.619										0.010
2015	0.768	0.754											0.014
	5&6 years holding periods												
2005	0.307	0.306	0.306	0.305	0.308	0.309	0.302	0.304	0.310	0.309	0.307	0.308	0.000
2006	0.391	0.393	0.393	0.395	0.390	0.389	0.398	0.395	0.388	0.389	0.392		-0.001
2007	0.427	0.427	0.427	0.431	0.418	0.427	0.432	0.424	0.400	0.404			0.023
2008	0.309	0.308	0.307	0.315	0.389	0.395	0.396	0.382	0.341				-0.032
2009	0.070	0.064	0.063	0.045	0.077	0.080	0.077	0.057					0.013
2010	0.012	0.001	0.002	-0.002	0.008	0.009	0.003						0.010
2011	0.081	0.086	0.086	0.086	0.086	0.085							-0.004
2012	0.171	0.172	0.172	0.175	0.166								0.005
2013	0.248	0.248	0.247	0.253									-0.005
2014	0.331	0.328	0.327										0.004
2015	0.389	0.379											0.010

Table 6: Revision summary statistics for housing in the Netherlands in 2005 – 2015.

Model	Avg.	Avg. ||.	Median ||	Min	Max	Std.Dev.	> 0.005	> 0.01	> 0.02	> 0.03	> 0.04
Standard	-0.616	0.618	0.531	-2.051	0.167	0.447	51.6%	20.7%	0.4%		
HP (-3)	0.124	0.143	0.101	-0.293	0.613	0.142	1.3%				
HP (-4)	0.156	0.163	0.119	-0.140	0.747	0.157	3.3%				
HP (-5)	0.117	0.157	0.113	-0.279	0.822	0.179	3.3%				
HP (-6)	0.067	0.149	0.119	-0.438	0.657	0.181	1.3%				
HP (-7)	-0.114	0.155	0.119	-0.651	0.331	0.171	2.9%				
HP (-8)	-0.202	0.215	0.171	-0.746	0.200	0.187	8.4%				
HP (-9)	-0.280	0.281	0.236	-0.949	0.101	0.216	19.3%				
HP (-10)	-0.320	0.385	0.312	-1.334	1.250	0.367	32.5%	4.6%			
Cst	-0.876	0.877	0.720	-2.978	0.035	0.626	65.9%	34.9%	5.7%		
Cst 3	0.712	0.726	0.625	-0.249	2.523	0.572	57.4%	26.6%	3.3%		
Cst 4	0.315	0.336	0.266	-0.237	1.360	0.294	23.1%	2.6%			
Cst 5	0.077	0.132	0.104	-0.314	0.802	0.156					
Cst 6	-0.082	0.118	0.092	-0.464	0.433	0.131					
Cst 7	-0.196	0.202	0.167	-0.689	0.169	0.169	5.9%				
Cst 8	-0.281	0.281	0.230	-0.967	0.028	0.216	18.5%				
Cst 9	-0.347	0.347	0.281	-1.190	0.021	0.257	26.2%	1.5%			
Cst 10	-0.400	0.400	0.325	-1.369	0.021	0.291	32.7%	3.3%			

The table provides statistics for $\mu_{t|\tau_2}$ - $\mu_{t|\tau_1}$, $\tau_2 > \tau_1 > t$, $t = 2005, \ldots, 2015$: Average (of the absolute value), median of the absolute value, minimum and maximum, and standard deviation, all $\times 100$. Finally, the percentage of revisions (absolute value) exceeding the thresholds in the first row.

Table 7: Revision summary statistics for housing in England & Wales in 2005 – 2015.

Model	Avg.	Avg. ||	Median ||	Min	Max	Std.Dev.	> 0.005	> 0.01	> 0.02	> 0.03	> 0.04
Standard	-0.447	0.472	0.260	-2.005	0.237	0.510	36.3%	17.0%	0.3%		
HP (-3)	0.492	0.493	0.439	-0.065	1.546	0.339	43.0%	9.3%	0.0%		
HP (-4)	0.372	0.374	0.303	-0.114	1.201	0.279	28.7%	3.0%			
HP (-5)	0.305	0.311	0.248	-0.199	1.039	0.248	20.7%	1.0%			
HP (-6)	0.166	0.208	0.155	-0.273	0.810	0.213	6.3%				
HP (-7)	-0.024	0.182	0.152	-0.574	0.553	0.229	4.0%				
HP (-8)	-0.306	0.328	0.203	-1.253	0.250	0.338	24.7%	4.7%			
HP (-9)	-0.528	0.529	0.369	-2.009	0.060	0.461	40.3%	17.0%	0.3%		
HP (-10)	-0.642	0.642	0.467	-2.475	-0.032	0.532	48.0%	22.0%	2.7%		
Cst	-0.314	0.377	0.247	-1.513	0.414	0.408	28.0%	8.3%			
Cst 3	0.283	0.320	0.251	-0.431	1.150	0.283	20.0%	1.7%			
Cst 4	0.134	0.215	0.162	-0.581	0.814	0.253	10.3%				
Cst 5	0.044	0.202	0.153	-0.692	0.676	0.257	7.0%				
Cst 6	-0.015	0.211	0.173	-0.766	0.614	0.270	7.0%				
Cst 7	-0.058	0.224	0.185	-0.834	0.575	0.283	10.7%				
Cst 8	-0.090	0.236	0.189	-0.919	0.546	0.294	12.0%				
Cst 9	-0.115	0.248	0.194	-0.985	0.528	0.305	14.7%				
Cst 10	-0.135	0.257	0.188	-1.038	0.515	0.313	16.0%	0.3%			

The table provides statistics for $\mu_{t|\tau_2}$ - $\mu_{t|\tau_1}$, $\tau_2 > \tau_1 > t$, $t = 2005, \ldots, 2015$: Average (of the absolute value), median of the absolute value, minimum and maximum, and standard deviation, all $\times 100$. Finally, the percentage of revisions (absolute value) exceeding the thresholds in the first row.

Table 8: Revision summary statistics for commercial real estate in the US in 2005 – 2015.

Model	Avg.	Avg. ||	Median ||	Min	Max	Std.Dev.	> 0.005	> 0.01	> 0.02	> 0.03	> 0.04
Standard	-2.237	2.317	1.504	-10.021	1.165	2.391	78.0%	61.8%	40.4%	27.9%	19.6%
HP (-3)	-0.458	0.980	0.746	-6.369	2.377	1.259	64.8%	38.2%	11.6%	4.0%	1.3%
HP (-4)	-0.959	1.637	1.234	-7.351	3.102	1.998	78.7%	57.6%	29.5%	12.7%	7.3%
HP (-5)	-0.170	1.002	0.676	-5.409	2.991	1.396	62.9%	36.5%	12.5%	5.9%	2.4%
HP (-6)	-0.687	1.009	0.725	-5.918	1.853	1.241	64.2%	35.8%	11.2%	4.8%	2.9%
HP (-7)	1.069	1.581	1.171	-3.699	6.864	1.819	74.3%	57.1%	31.4%	13.8%	6.2%
HP (-8)	0.919	1.332	0.978	-3.025	6.039	1.529	69.2%	49.7%	23.7%	7.7%	4.6%
HP (-9)	1.530	2.030	1.445	-5.094	7.870	2.252	76.3%	62.9%	39.6%	24.2%	17.8%
HP (-10)	3.324	3.449	2.456	-1.823	20.788	3.727	86.2%	75.4%	57.8%	44.2%	32.3%
Cst	2.506	2.566	2.038	-2.193	10.475	2.196	84.4%	74.5%	50.8%	33.2%	20.7%
Cst 3	-0.848	1.043	0.733	-5.519	1.560	1.147	62.6%	40.4%	14.3%	4.0%	2.2%
Cst 4	-0.010	0.780	0.612	-3.180	3.745	1.039	55.8%	28.6%	7.5%	1.3%	
Cst 5	0.494	0.883	0.575	-1.970	5.055	1.138	55.6%	31.6%	10.1%	3.3%	1.3%
Cst 6	0.829	1.064	0.658	-1.723	5.929	1.260	61.8%	35.8%	17.8%	5.7%	2.2%
Cst 7	1.068	1.228	0.781	-1.790	6.553	1.366	65.9%	42.2%	21.5%	11.9%	3.3%
Cst 8	1.248	1.369	0.928	-1.841	7.036	1.455	68.1%	46.8%	23.5%	13.4%	4.4%
Cst 9	1.388	1.490	1.062	-1.880	7.418	1.528	70.1%	51.4%	26.6%	15.4%	7.5%
Cst 10	1.500	1.589	1.164	-1.911	7.724	1.589	72.3%	55.2%	29.0%	16.7%	9.7%

The table provides statistics for $\mu_{t|\tau_2}$ - $\mu_{t|\tau_1}$, $\tau_2 > \tau_1 > t$, $t = 2005, \ldots, 2015$: Average (of the absolute value), median of the absolute value, minimum and maximum, and standard deviation, all $\times 100$. Finally, the percentage of revisions (absolute value) exceeding the thresholds in the first row.

Table 9: Revision of holding period coefficients for housing in the Netherlands.

HP \Year	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005
3	0.020	0.021	0.021	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.019	0.019
4	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.011	0.010	0.010
5	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004
7	-0.006	-0.006	-0.005	-0.004	-0.004	-0.003	-0.003	-0.002	-0.001	0.000	0.000	0.000
8	-0.014	-0.014	-0.012	-0.011	-0.010	-0.009	-0.008	-0.007	-0.005	-0.005	-0.004	-0.004
9	-0.022	-0.020	-0.018	-0.016	-0.015	-0.014	-0.012	-0.010	-0.008	-0.008	-0.007	-0.009
10	-0.033	-0.030	-0.026	-0.024	-0.022	-0.020	-0.017	-0.014	-0.013	-0.012	-0.013	-0.017
11	-0.040	-0.035	-0.032	-0.028	-0.026	-0.022	-0.019	-0.016	-0.014	-0.014	-0.016	-0.018
12	-0.050	-0.045	-0.041	-0.037	-0.032	-0.028	-0.024	-0.020	-0.017	-0.016	-0.017	-0.025
13	-0.062	-0.057	-0.053	-0.046	-0.042	-0.036	-0.031	-0.027	-0.023	-0.019	-0.021	
14	-0.072	-0.066	-0.061	-0.054	-0.050	-0.045	-0.043	-0.039	-0.034	-0.036		
15	-0.082	-0.076	-0.070	-0.066	-0.063	-0.058	-0.056	-0.050	-0.044			
16	-0.096	-0.090	-0.085	-0.080	-0.076	-0.073	-0.067	-0.055				
17	-0.100	-0.094	-0.090	-0.082	-0.079	-0.076	-0.073					
18	-0.115	-0.109	-0.103	-0.102	-0.099	-0.091						
19	-0.121	-0.118	-0.119	-0.120	-0.110							
20	-0.130	-0.127	-0.135	-0.145								
21	-0.136	-0.142	-0.140									
22	-0.147	-0.135										

Table 10: Revision of holding period coefficients for housing in England & Wales.

HP \Year	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005
3	0.025	0.025	0.024	0.023	0.023	0.023	0.022	0.022	0.021	0.021	0.022	0.022
4	0.016	0.016	0.016	0.015	0.015	0.014	0.014	0.013	0.013	0.013	0.013	0.014
5	0.008	0.008	0.007	0.007	0.007	0.006	0.006	0.006	0.005	0.005	0.006	0.007
7	-0.009	-0.009	-0.008	-0.008	-0.007	-0.006	-0.006	-0.005	-0.004	-0.004	-0.004	-0.004
8	-0.019	-0.017	-0.016	-0.013	-0.011	-0.010	-0.008	-0.006	-0.005	-0.005	-0.006	-0.007
9	-0.029	-0.026	-0.022	-0.018	-0.015	-0.013	-0.010	-0.008	-0.006	-0.006	-0.005	-0.005
10	-0.038	-0.032	-0.027	-0.023	-0.018	-0.015	-0.012	-0.009	-0.008	-0.006	-0.005	-0.001
11	-0.043	-0.035	-0.030	-0.026	-0.021	-0.018	-0.015	-0.012	-0.009	-0.004	0.001	
12	-0.046	-0.038	-0.034	-0.032	-0.028	-0.026	-0.022	-0.019	-0.013	-0.006		
13	-0.045	-0.038	-0.036	-0.035	-0.032	-0.030	-0.026	-0.025	-0.023			
14	-0.045	-0.040	-0.039	-0.038	-0.035	-0.032	-0.024	-0.021				
15	-0.044	-0.042	-0.040	-0.040	-0.036	-0.030	-0.027					
16	-0.048	-0.046	-0.047	-0.047	-0.041	-0.036						
17	-0.050	-0.048	-0.049	-0.048	-0.042							
18	-0.054	-0.053	-0.052	-0.049								
19	-0.058	-0.051	-0.043									
20	-0.059	-0.053										
21	-0.069											

Table 11: Revision of coefficient for constant for housing in the Netherlands, and England & Wales and commercial real estate in the US..

	Housing NL			Housing England&Wales			Commercial US		
Year	Const	HP	Const/HP	Const	HP	Const/HP	Const	HP	Const/HP
2005	0.029	5.3	0.006	0.037	4.7	0.008	0.195	4.3	0.045
2006	0.028	5.5	0.005	0.034	4.9	0.007	0.193	4.4	0.044
2007	0.028	5.7	0.005	0.031	5.1	0.006	0.176	4.4	0.040
2008	0.030	5.9	0.005	0.031	5.2	0.006	0.175	4.5	0.039
2009	0.031	6.0	0.005	0.032	5.3	0.006	0.175	4.6	0.038
2010	0.034	6.1	0.006	0.034	5.5	0.006	0.170	4.7	0.036
2011	0.036	6.3	0.006	0.035	5.7	0.006	0.157	4.9	0.032
2012	0.038	6.4	0.006	0.036	5.9	0.006	0.157	5.2	0.030
2013	0.041	6.6	0.006	0.037	6.1	0.006	0.153	5.4	0.028
2014	0.044	6.8	0.006	0.038	6.4	0.006	0.145	5.7	0.026
2015	0.047	7.1	0.007	0.038	6.7	0.006	0.142	5.9	0.024
2016	0.049	7.4	0.007	0.039	7.0	0.006	0.140	6.1	0.023

C Appendix

[Place Table 9 about here]

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