



Repeat sales models, holding periods and index revision

Marc Francke

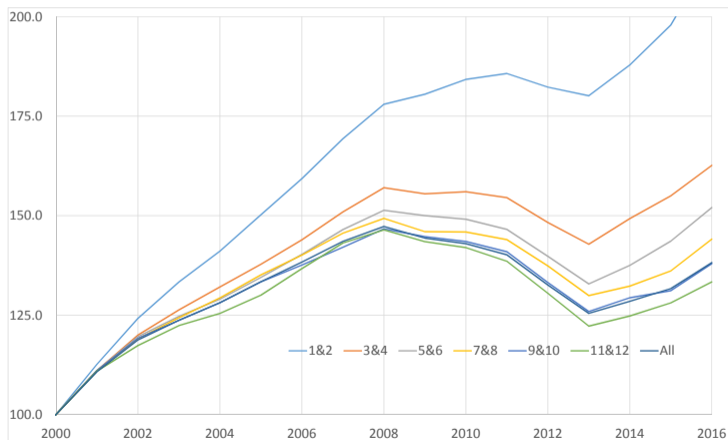
University of Amsterdam, Ortec Finance

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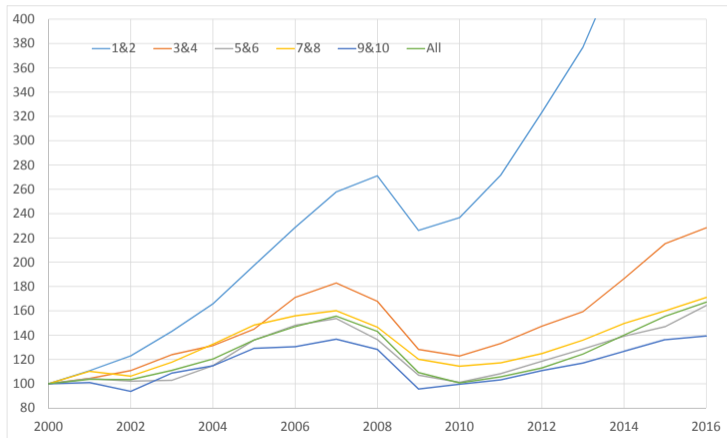
Introduction

- Relation between holding periods and
 - average annualized returns
 - index revisionin repeat sales models
- Data: NL housing (1 million pairs) and US CRE (43,000 pairs)

Indices and holding period (NL housing)



Indices and holding period (US CRE)



Indices and holding period: Stats

Holding Period	NL Housing		US CRE	
	Avg.	St.Dev	Avg.	St.Dev
1&2	0.072	0.050	0.117	0.090
3&4	0.055	0.053	0.052	0.108
5&6	0.051	0.054	0.031	0.101
7&8	0.049	0.055	0.034	0.087
9&10	0.047	0.057	0.021	0.101
11&12	0.046	0.058		
All	0.047	0.056	0.032	0.101

Short (long) holding periods have large (small) annualized returns

Returns depend on holding period

■ Why?

- Capital expenditures right after purchase (Goetzmann, 1992)
- Disposition effect (Bokhari & Geltner, 2011)
Investors tend to sell more quickly 'winners' and to hold onto lower-performing properties longer

■ Consequences

■ Forecasting

Year	Standard RS		RS holding period	
	2 sales	3 sales	2 sales	3 sales
2004	Initial sale price 100,000			
Forecast of sales price				
2010		111,583		115,554
2016	107,860	107,860	106,319	117,828

- Standard repeat sales model is misspecified
(assumes equal returns for all holding periods)

Revision

- Revision in RS due to periodically adding combinations of new and old sales

- Year from = 1993

Year to	Holding period	# sales	Cum. # sales	% of total
1996	3	6837	6837	3.9%
1997	4	7576	14413	8.2%
1998	5	7478	21891	12.5%
1999	6	6429	28320	16.1%

- No **systematic** revision when RS samples were 'random' subsamples of all sales. Then only loss of efficiency in price index estimates (Shiller 1993, Macro Market, Ch. 8)
- If not, then potential systematic bias in price index
- Not random with respect to holding period (early in sample)

Systematic revisions?

- Clapp and Giaccotto (REE, 1999)
 - 'The insensitivity of the magnitude of revisions to large increases in sample sizes suggests that revisions are driven by some **systematic** factor, independent of the addition of information through more transactions'
 - Revisions are more likely to be downward than upward.
 - Excluding flips 'solves' the revision problem
- Clapham, Englund, Quigley and Redfearn (REE, 2006)
 - 'Hedonic indexes appear to be substantially more stable than RS indexes and are not prone to the systematic downward revision found in the RS indexes.'
- Deng, Quigley (JREFE, 2008)
 - **Substantial index revision**: 'in about one quarter of the 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%.'
 - **No systematic biases**: arbitrary revisions
 - **No Predictability**: Little evidence that revisions are strongly predictable

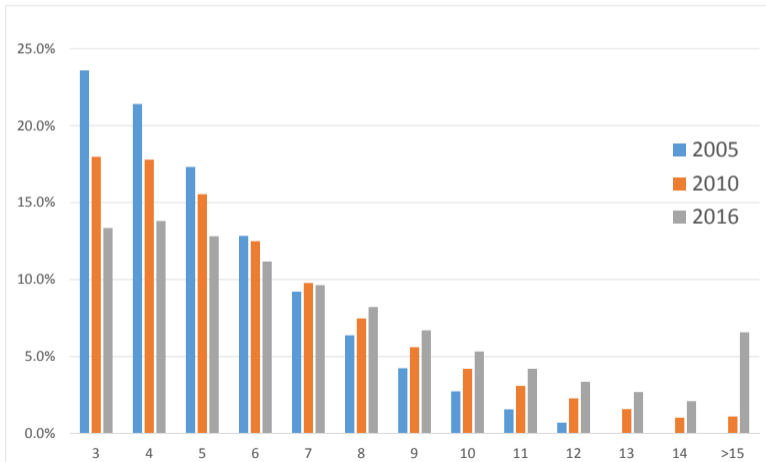
Literature on revisions and holding period

- Apart from Clapp and Giaccotto (REE, 1999) no relation between revision and holding period (only flips)
- Literature on holding period concerns variance of error term (secondary effect)

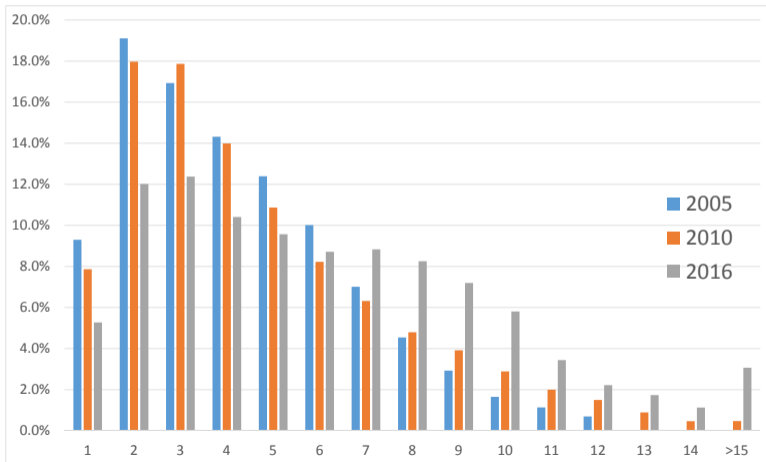
Holding Period

Second sale Year	NL housing (1993)			US CRE (1992)		
	Holding period		Pairs	Holding period		Pairs
Average	Cumulative	Average		Cumulative		
2000	4.7	4.2	112,087	3.4	3.4	187
2001	5.1	4.4	155,413	3.8	3.6	498
2002	5.4	4.7	204,883	4.0	3.8	930
2003	5.7	4.9	256,691	4.2	4.0	1,606
2004	6.0	5.1	312,654	4.3	4.1	2,909
2005	6.2	5.3	378,410	4.4	4.3	5,464
2006	6.6	5.5	449,497	4.5	4.4	8,133
2007	7.0	5.7	518,442	4.5	4.4	11,375
2008	7.3	5.9	584,259	5.2	4.5	13,375
2009	7.6	6.0	629,541	5.4	4.6	14,483
2010	8.0	6.1	674,653	5.6	4.7	16,294
2011	8.4	6.3	718,110	6.1	4.9	19,035
2012	9.0	6.4	760,085	6.5	5.1	22,574
2013	9.5	6.6	798,024	6.9	5.4	26,692
2014	9.9	6.8	854,026	7.0	5.7	31,759
2015	10.4	7.1	924,892	7.3	5.9	37,424
2016	10.7	7.4	1,017,064	7.2	6.1	42,880

Frequency distribution holding period NL housing



Frequency distribution holding period US CRE



Revision NL Housing All holding periods

Year	I2016	I2015	I2014	I2013	I2012	I2011	I2010	I2009	I2008	I2007	I2006	I2005	Last - First
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

- Index base year: 2000
- Number of pairs: 1 million
- Revision about 2% points and **systematic downwards**

Revision NL Housing Holding Periods 6&7

Year	I2016	I2015	I2014	I2013	I2012	I2011	I2010	I2009	I2008	I2007	I2006	I2005	Last-First
2005	0.292	0.293	0.295	0.296	0.295	0.292	0.294	0.296	0.297	0.297	0.297	0.295	-0.003
2006	0.332	0.333	0.333	0.333	0.331	0.332	0.332	0.333	0.333	0.333	0.333		-0.001
2007	0.378	0.378	0.377	0.376	0.378	0.378	0.378	0.377	0.377	0.377			0.002
2008	0.405	0.404	0.401	0.407	0.408	0.408	0.406	0.405	0.404				0.001
2009	0.387	0.384	0.391	0.394	0.395	0.394	0.391	0.389					-0.002
2010	0.378	0.384	0.387	0.390	0.390	0.388	0.385						-0.006
2011	0.372	0.374	0.376	0.377	0.376	0.375							-0.003
2012	0.319	0.320	0.321	0.321	0.320								-0.001
2013	0.270	0.270	0.270	0.269									0.001
2014	0.294	0.293	0.291										0.002
2015	0.325	0.323											0.002

- Index base year: 2000
- Number of pairs: 200,000
- Revision about 0.5% points and **no systematic revision**

Revision US CRE All holding periods

Year	I2016	I2015	I2014	I2013	I2012	I2011	I2010	I2009	I2008	I2007	I2006	Last-First
2005	0.307	0.310	0.303	0.298	0.299	0.301	0.302	0.304	0.308	0.316	0.329	-0.022
2006	0.385	0.388	0.387	0.388	0.393	0.399	0.401	0.402	0.405	0.416	0.427	-0.041
2007	0.442	0.447	0.447	0.454	0.459	0.470	0.473	0.484	0.494	0.505		-0.063
2008	0.358	0.367	0.368	0.376	0.392	0.408	0.424	0.438	0.443			-0.085
2009	0.088	0.091	0.088	0.088	0.095	0.112	0.132	0.142				-0.054
2010	0.007	0.012	0.006	0.010	0.024	0.046	0.054					-0.048
2011	0.056	0.062	0.068	0.082	0.100	0.113						-0.057
2012	0.122	0.132	0.145	0.162	0.173							-0.051
2013	0.218	0.236	0.251	0.260								-0.042
2014	0.337	0.358	0.365									-0.029
2015	0.442	0.457										-0.015

- Index base year: 2000
- Number of pairs: about 43,000
- Revision about 5% points and **systematic downwards**

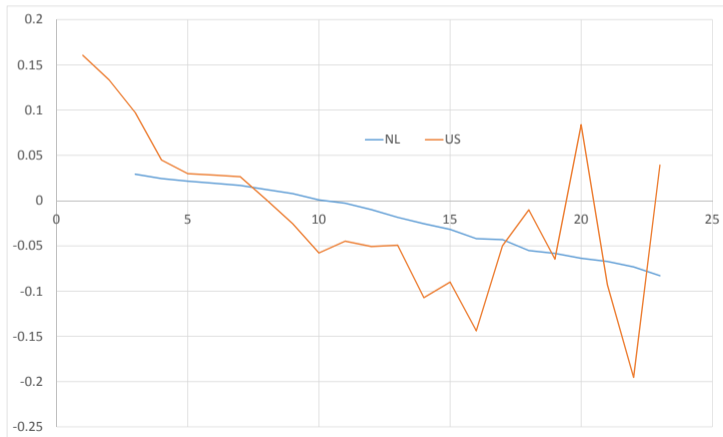
Revision US CRE Holding periods 6&7

Year	I2016	I2015	I2014	I2013	I2012	I2011	I2010	I2009	I2008	I2007	I2006	Last-First
2005	0.341	0.347	0.345	0.345	0.338	0.368	0.352	0.341	0.336	0.340	0.345	-0.005
2006	0.390	0.392	0.391	0.391	0.383	0.380	0.375	0.372	0.370	0.372	0.373	0.016
2007	0.461	0.459	0.459	0.459	0.469	0.472	0.478	0.482	0.484	0.482		-0.022
2008	0.379	0.372	0.374	0.375	0.381	0.389	0.409	0.422	0.428			-0.049
2009	0.164	0.140	0.125	0.125	0.124	0.144	0.188	0.217				-0.054
2010	0.115	0.141	0.136	0.136	0.131	0.157	0.216					-0.101
2011	0.131	0.140	0.138	0.138	0.131	0.160						-0.029
2012	0.166	0.170	0.169	0.169	0.161							0.005
2013	0.263	0.263	0.263	0.263								0.000
2014	0.404	0.400	0.401									0.003
2015	0.474	0.463										0.011

- Index base year: 2000
- Number of pairs: about 7,500
- Revision larger due to relative low number of observations in earlier years

Repeat sales model is misspecified

Average residual by holding period



How to reduce revision?

- Standard RS model

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

where

$$d_i^\mu = \left(\underbrace{0 \dots 0}_{1, \dots, s-1} \quad \underbrace{-1}_s \quad \underbrace{0 \dots 0}_{s+1, \dots, t-1} \quad \underbrace{1}_t \quad \underbrace{0 \dots 0}_{t+1, \dots, T} \right)$$

- Estimated RS index can be expressed as a matrix weighted average of holding period specific RS indices, where weights depend on number of pairs for each holding period
- Two extensions:
 - include holding period dummy variables
 - include constant

Include holding period dummy variables

- RS Holding period dummy variables (leave out 1 holding period)

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

where $e_i = \left(\underbrace{0 \dots 0}_{m, \dots, t-s-1} \quad \underbrace{1}_{t-s} \quad \underbrace{0 \dots 0}_{t-s+1, \dots, T} \right)$

- Residuals do not depend on which holding period is left out (identical models)
- Indices **do depend** on holding period
 - Index conditional on the left-out holding period
 - Difference in index return between left-out HP k and l is a constant

$$\Delta \mu_t^{(-l)} = \Delta \mu_t^{(-k)} + \frac{1}{l} \delta_l^{(-k)},$$

- Second moments of returns (volatility, (auto)correlation) are identical.
- Size of revisions do depend on left-out holding period (next slides)

Include constant

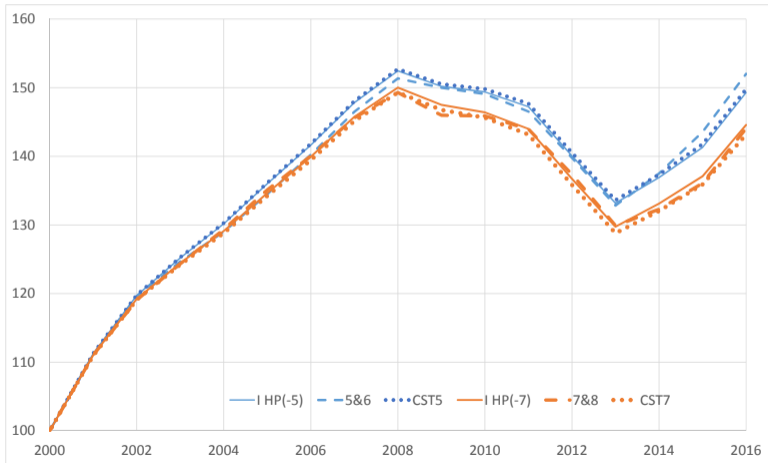
- Including dummy variables per holding period is not parsimonious
- Relation between residuals and holding period is almost linear
- (It is not possible to add linear term because of perfect collinearity)
- Include constant

$$r_{i,s,t} = \alpha + d_i^{\mu} \mu + \varepsilon_{i,t} - \varepsilon_{i,s}$$

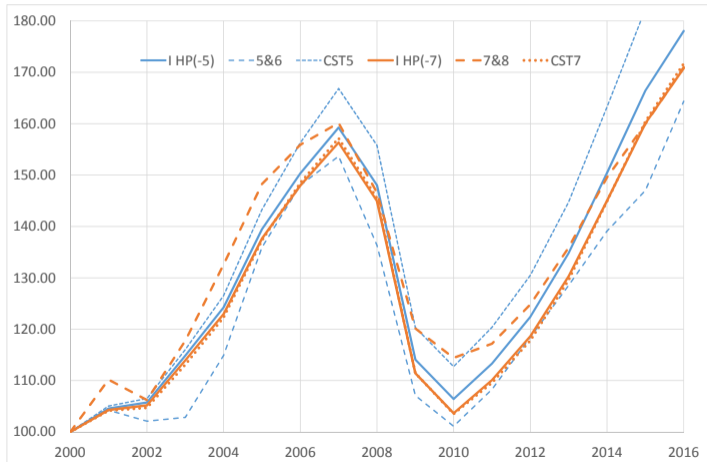
- Index return for l period holdings is

$$\Delta \mu_t^{(l)} = \Delta \mu_t + \alpha/l,$$

Comparison of indices (NL housing)



Comparison of indices (US CRE)



Results Coefficients Holding Period

- Coefficients for holding periods are also updated over time (NL housing)

HP\Year	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003
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	0.018	0.016
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	0.008	0.007
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	0.003	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	0.000	-0.001
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	-0.005	-0.006
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	-0.011	-0.014
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	-0.021	-0.020
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	-0.019	
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												
23	-0.162													

Results Coefficients Holding Period

- Coefficients for constant are also updated over time

Year	NL Housing			US CRE		
	Const	HP	Const/HP	Const	HP	Const/HP
2003	0.027	4.9	0.006			
2004	0.029	5.1	0.006			
2005	0.029	5.3	0.006	0.215	4.3	0.050
2006	0.028	5.5	0.005	0.211	4.4	0.049
2007	0.028	5.7	0.005	0.194	4.4	0.044
2008	0.030	5.9	0.005	0.191	4.5	0.042
2009	0.031	6.0	0.005	0.190	4.6	0.042
2010	0.034	6.1	0.006	0.184	4.7	0.039
2011	0.036	6.3	0.006	0.170	4.9	0.035
2012	0.038	6.4	0.006	0.168	5.1	0.033
2013	0.041	6.6	0.006	0.163	5.4	0.030
2014	0.044	6.8	0.006	0.155	5.7	0.027
2015	0.047	7.1	0.007	0.152	5.9	0.026
2016	0.049	7.4	0.007	0.149	6.1	0.025
Last/First	1.796		1.184	0.693		0.486

- Explanation for different behavior Housing and CRE?

Revision Statistics NL Housing

Level	Avg.	Avg.	Median	Min	Max	Std.Dev.	> 0.005	> 0.01	> 0.02
Standard	-0.616	0.618	0.531	-2.051	0.167	0.447	51.6%	20.7%	0.4%
Dum HP (-3)	0.124	0.143	0.101	-0.293	0.613	0.142	1.3%	0%	0%
Dum HP (-4)	0.156	0.163	0.119	-0.140	0.747	0.157	3.3%	0%	0%
Dum HP (-5)	0.117	0.157	0.113	-0.279	0.822	0.179	3.3%	0%	0%
Dum HP (-6)	0.067	0.149	0.119	-0.438	0.657	0.181	1.3%	0%	0%
Dum HP (-7)	-0.114	0.155	0.119	-0.651	0.331	0.171	2.9%	0%	0%
Dum HP (-8)	-0.202	0.215	0.171	-0.746	0.200	0.187	8.4%	0%	0%
Dum HP (-9)	-0.280	0.281	0.236	-0.949	0.101	0.216	19.3%	0%	0%
Dum HP (-10)	-0.320	0.385	0.312	-1.334	1.250	0.367	32.5%	4.6%	0%
CST	-0.876	0.877	0.720	-2.978	0.035	0.626	65.9%	34.9%	5.7%
CST3	0.712	0.726	0.625	-0.249	2.523	0.572	57.4%	26.6%	3.3%
CST4	0.315	0.336	0.266	-0.237	1.360	0.294	23.1%	2.6%	0%
CST5	0.077	0.132	0.104	-0.314	0.802	0.156	1.3%	0%	0%
CST6	-0.082	0.118	0.092	-0.464	0.433	0.131	0%	0%	0%
CST7	-0.196	0.202	0.167	-0.689	0.169	0.169	5.9%	0%	0%
CST8	-0.281	0.281	0.230	-0.967	0.028	0.216	18.5%	0%	0%
CST9	-0.347	0.347	0.281	-1.190	0.021	0.257	26.2%	1.5%	0%
CST10	-0.400	0.400	0.325	-1.369	0.021	0.291	32.7%	3.3%	0%

Revision Statistics US CRE

Level	Avg.	Avg.	Median	Min	Max	Std.Dev.	> 0.005	> 0.01	> 0.02	> 0.03	> 0.04	> 0.05
Standard	-1.825	1.908	1.340	-8.508	1.174	1.840	77.0%	58.6%	36.4%	23.4%	15.6%	7.7%
Dum HP (-3)	-0.621	1.039	0.784	-6.597	2.015	1.264	66.5%	40.9%	12.7%	4.8%	1.4%	1.0%
Dum HP (-4)	-0.828	1.432	1.105	-7.190	2.839	1.767	73.9%	53.6%	25.1%	8.9%	4.5%	3.6%
Dum HP (-5)	-0.222	0.969	0.711	-5.685	2.530	1.313	64.1%	35.6%	11.7%	3.8%	1.7%	0.5%
Dum HP (-6)	-0.672	0.986	0.704	-5.425	1.831	1.207	63.9%	34.9%	10.5%	5.0%	3.1%	0.5%
Dum HP (-7)	1.063	1.481	1.126	-3.262	6.685	1.697	71.5%	55.5%	29.2%	10.3%	5.0%	3.8%
Dum HP (-8)	0.832	1.282	0.903	-2.925	5.870	1.554	66.5%	46.4%	22.0%	7.9%	4.5%	2.4%
Dum HP (-9)	1.842	2.034	1.429	-2.186	7.745	2.038	73.2%	62.0%	39.7%	24.9%	18.2%	10.3%
Dum HP (-10)	2.861	3.001	2.363	-1.944	12.513	2.691	85.2%	74.4%	55.0%	41.4%	29.9%	22.0%
CST	3.178	3.186	2.608	-0.279	11.852	2.469	90.0%	80.6%	61.2%	44.0%	30.4%	21.3%
CST3	-0.971	1.095	0.745	-5.759	1.195	1.165	63.6%	38.8%	18.4%	4.8%	2.4%	1.2%
CST4	0.066	0.772	0.602	-2.983	3.371	1.014	56.5%	28.7%	6.0%	0.5%	0.0%	0.0%
CST5	0.689	0.956	0.603	-1.555	4.965	1.147	58.6%	32.3%	15.6%	4.1%	1.4%	0.0%
CST6	1.104	1.214	0.762	-0.820	6.027	1.307	62.2%	40.9%	23.0%	11.0%	3.1%	1.7%
CST7	1.400	1.453	0.991	-0.664	6.800	1.445	69.4%	49.8%	26.8%	15.6%	6.0%	2.2%
CST8	1.622	1.656	1.196	-0.548	7.391	1.558	73.0%	56.7%	31.3%	18.9%	9.6%	3.3%
CST9	1.795	1.821	1.352	-0.457	7.850	1.650	75.6%	60.3%	35.2%	21.1%	12.9%	5.0%
CST10	1.933	1.955	1.488	-0.384	8.218	1.726	80.9%	62.2%	38.3%	22.2%	13.9%	7.2%

Results

- Revision in holding period RS models (or model with constant) are much smaller than in standard repeat sales models
 - results dependent on left-out holding period (related to average holding period)
- Sensitivity analysis
 - results are robust to WLS, percentiles of first sales, ...
- Alternative specifications for holding period
 - Constant: restrictive model
 - Dummy variable for each holding period: too many parameters (high frequency)
 - Replace dummy variables by some flexible (stochastic) function

Conclusion

- Average annualized returns depend on holding periods
 - short (long) holding periods have large (small) annualized returns having consequences for forecasting
- Standard repeat sales model is misspecified
- Possible to create a constant holding period index (either 1 holding period or a weighted average)
- Revisions are due to changing holding periods over time
- Revisions can partly be resolved by correcting for holding periods
- It takes a long time for a repeat sales database to mature
change in frequency distribution of holding period is negligible