Serial Persistence and Risk Structure of Local Housing Market

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Abstract

This paper investigated serial correlations and the risk structure of local house price movements for single family homes. It was found house price changes were strongly correlated over time, but the market risk structure (variance of price changes) was specific to location differences and varied largely depending on different measurement intervals. For the monthly measurement interval the market risk was close to a linear form. However, measured quarterly the market risk tended to follow a quadratic form for a shorter time period up to 8 quarters and after that the actual risk form seemed to sit in between the linear and quadratic forms. These findings have important implications in developing a house price index based on the weighted repeated sales (WRS) method.

Keywords: Risk structure, Variance ratio, Measurement intervals, SPAR index, Weighted repeated sales (WRS) index

1. Introduction

It is widely believed that there is considerable persistence in real estate price movements. Finding autocorrelation in real estate returns[1] is not new, but there is limited research of how the holding-period variance of returns (which is referred to the market risk structure) evolves over time. In the finance literature, it is commonly assumed the variance of stock returns grows in a linear form. This assumption is mainly based on the efficient market hypothesis proposed by Fama (1965). Even though some empirical evidence suggests stock returns can be serially correlated and market prices may not follow random walks (Lo and MacKinlay, 1988, Campbell et al., 1997), many financial researchers still tend to accept the above assumption due to the relatively efficient nature of stock markets.

Compared to stock markets, real estate markets are less efficient and have more inertia in price movements. Thus the linear form assumption, which is implied from the finance literature, may not apply to real estate markets. Recently, Lin and Liu (2008) proposed a new real estate risk structure whereby the variance of returns increased linearly with the square of the holding period (this corresponds to the quadratic form assumption). They found that such a risk structure was reasonably supported in their empirical study based on the Office of Federal Housing Enterprise Oversight (OFHEO) home price index in the U.S. from 1975Q1 to 2006Q3.

[1] The income change is believed to be stable, therefore the difference between return and price change is small. In practice, forecasts of returns and forecasts of price changes are very similar (Campbell and Shiller, 2001). Unless stated otherwise, we take returns to be the log index differences of market price movements over time on a continuous compounding basis.

In this paper, we found the risk structure of local housing markets was locationally specific and the actual risk forms could vary due to different measurement intervals. These findings have important implications in developing a house price index based on the weighted repeated sales (WRS) method as proposed by Case and Shiller (1987). In the traditional WRS method it is assumed the variance of error term for each pair sales grows proportionally with time. However, if the market risk structure does not increase linearly over the holding period, it is more likely that the variance of error term between each pair sales will also not grow linearly as well.

This paper differs from previous research in the following two areas. First, it utilised two quality controlled indexing methods in the empirical study to minimise the problem of choice for house price indices. All price indices were directly calculated from the market transaction data. A complete data set ensures any bias due to late sales reporting on the index construction is eliminated. The indexing method included the sale price appraisal ratio (SPAR) method which uses all transaction data, and the traditional weighted repeat sales (WRS) method developed by Case and Shiller (1987). Second, we investigated the real estate market risk for both monthly and quarterly measurement intervals. All previous studies on testing the risk structure of real estate returns have been based on quarterly data. Compared to quarterly observations over the same time period, monthly data increases actual observations and better addresses volatility-based questions. It was interesting to observe if the frequency of measurement intervals had a significant impact on the form of market risk.

The remainder of the study is organised as follows: Section 2 reviews the literature on house price indices. Section 3 presents the theoretical framework and econometric tools used in this research. Section 4 describes the data utilised. Section 5 reports the empirical results. Section 6 provides a conclusion.

2. The Weighted Repeat Sales Method and SPAR Technique

The repeat sales method was first proposed by Bailey, Muth, and Nourse (1963) and has been often referred to in the literature as the "BMN method". Based on the BMN method, Case and Shiller (1987, 1989) further developed the repeat sales method into the Weighted Repeat Sales (WRS) method. Their main point was the variance of the error term was linearly related to the time interval between sales rather than being constant as in the BMN method. A three-step weighted least square regression was used to weight down the influence of sales with longer time intervals. In the early 1990s Abraham and Schauman (1991) proposed a modified version of Case and Shiller's method. They believed the variance couldn't grow over time without restriction and proposed to use a quadratic equation instead of a linear equation to estimate the variance of error. Their method was used to produce the house price index for the U.S. Office of Federal Housing Enterprise Oversight (Calhoun, 1996).

More recently, Cheng, Lin and Liu (2009) challenged the linear assumption used in Case-Shiller model for step-two of WRS. Property returns over time are determined by three factors: a market return, a property-specific return and a random noise. If these three factors are assumed to be uncorrelated, the variance of error term between the paired log prices should be the sum of variances of the above three factors. They argued that either omitting the market risk or assuming it is in a linear form, could cause the WRS index to be inaccurate[2]. Nevertheless, Case-Shiller's repeat sales method has become a primary approach used for developing house price indices.

Other problems associated with the repeat sales method have been also reported in the literature. As the repeat sales method uses only repeated sales for index construction, the index is more prone to sample selection bias than other index methods which use all transaction sales. It has been found that the frequently traded houses (sold more than twice within a period of time) are more likely to be the "starter" houses or houses for opportune buyers (Haurin and Hendershott, 1991, Clapp and Giaccotto, 1992). Furthermore, the repeated sales tend to appreciate faster than the general housing market. As a result, the repeat sales method may overstate the price appreciation in general (Case et al., 1997). Use of building permit information to exclude certain repeated sales helps to minimise the quality change problem but some cosmetic improvements between repeated sales are not easily monitored. Even if there is no change in characteristics between repeat sales, the dwellings may not be identical due to building depreciation (Englund et al., 1999, Goetzmann and Spiegel, 1995). Finally, Clapham, Englund, Quigley and Redfearn (2006) found that the repeat sales index was prone to a systematic downward revision due to lagged sales.

The SPAR index is calculated by using the ratios of current property sale prices to their respective assessed values. This can be viewed as an arithmetic form of the repeat sales method proposed by Shiller (1991). The only difference between the SPAR technique and Shiller's arithmetic form of the repeat sales method is that

[2] Case and Shiller (1989) provided some reasons why they omitted the market risk in the second-step of WRS. It is assumed that the individual house price changes are not so heavily influenced by the aggregated market price.

assessed values are used as the base-period sale prices in the SPAR technique rather than being “inferred from their other prices using the estimated index” (Shiller, 1991).

The equally weighted form of a SPAR index, which is utilised in this paper, is given as follows:

$$\begin{cases} SPAR_t = \dfrac{\sum_{i=1}^{n_t} P_{it}/V_{i0}}{n_t} \\ I_t = \dfrac{SPAR_t}{SPAR_{t-1}} I_{t-1} \end{cases} \tag{1}$$

where $SPAR_t$ is the SPAR ratio at time period t, I_t is the SPAR index at time period t. n_t is the total number of sales at time period t. P_{it} represents the ith property sold at time period t. V_{i0} is the i^{th} property’s assessed value.

The SPAR technique has two distinctive advantages over the repeat sales method. First, it uses all sales transactions. Thus, sample size is increased and sample selection bias is minimised. Second, unlike the chained nature of the repeat sales method, under the SPAR technique lagged sales affect only their respective sale period and avoids the chained index revision problem.

The main limitation of applying the SPAR method is that there must be a robust property tax (rating) system. That is, valuations must be statistically reliable at reassessment dates, data bases well-maintained during the rating period and valuations regularly reassessed. For these reasons, the SPAR method is not yet widely used internationally and there is a paucity of literature relating to the SPAR technique.

More recent work on the SPAR index from Shi, Young and Hargreaves (2009) showed there was a trade-off between the measurement errors in assessed values and the frequency of reassessments. However the random measurement errors in assessed values were not important for the SPAR index as long as there were sufficient sales.

3. Testing for the Market Risk Structure

The use of serial correlation is the most direct and intuitive test for assessing the nature of returns over time. When an asset has zero autocorrelation in returns over all lags, the variance of returns is directly proportional to the length of the asset's holding periods. For testing of high-order serial correlation, we used the Ljung-Box Q-statistics. The null hypothesis of Q-statistics is that there is no autocorrelation (all Q statistics should be insignificant) up to that particular order.

Another set of statistical tools for testing the risk structure is called the variance ratio analysis introduced by Lo and MacKinlay (1988). The method was developed for testing the random walk hypothesis. If a price series follows a random walk, the variance ratio of its price changes should be equal to one. Through observing the variance ratio changes over time, it is possible to compare whether the risk structure is close to the linear form or follows a quadratic model. Gu (2002) studied the quarterly house price changes across the entire United States from 1975 to 1999. By analysing the variance ratios in returns, he found the returns were partly predictable but the patterns differed across local markets. More recently, Schindler et al. (2010) used the variance ratio analysis in testing the predictability and efficiency of securitised real estate markets for 14 countries. In general, assuming the sample consists of $nq+1$ observations, the variance ratio *VR(q)* can be derived as:

$$VR(q) = \frac{Var[r_t(q)]}{q \times Var[r_t]} \quad (3)$$

$$Var[r_t(q)] = \frac{1}{m}\sum_{t=q}^{nq}(p_t - p_{t-q} - q\hat{\mu})^2$$

and

$$Var[r_t] = \frac{1}{(nq-1)}\sum_{t=1}^{nq}(p_t - p_{t-1} - \hat{\mu})^2$$

where

$$m = q(nq - q + 1)\left(1 - \frac{q}{nq}\right)$$

$$\hat{\mu} = \frac{1}{nq}(p_{nq} - p_0)$$

$$p_t = \log(P_t)$$

q = the time interval

n = number of observations at q

The asymptotic standard normal test statistic of the variance ratio under the assumption of homoscedasticity in the r_t's is given as:

$$z(q) = \frac{\sqrt{nq}\,(VR(q)-1)}{\sqrt{2(2q-1)(q-1)/3q}} \quad (4)$$

The asymptotic standard normal test statistic for the heteroskedasticity-consistent estimator is:

$$z^*(q) = \frac{\sqrt{nq}\,(VR(q)-1)}{\sqrt{\theta(q)}} \quad (5)$$

where

$$\theta(q) = 4\sum_{k=1}^{q-1}\left(1-\frac{k}{q}\right)^2 \zeta(k)$$

$$\zeta(k) = \frac{nq\sum_{j=k+1}^{nq}(p_j - p_{j-1} - \hat{\mu})^2 (p_{j-k} - p_{j-k-1} - \hat{\mu})^2}{\left[\sum_{j=1}^{nq}(p_j - p_{j-1} - \hat{\mu})^2\right]^2}$$

4. Data and Preparation

House price movements for six selected cities were estimated directly from the transaction data supplied by Quotable Value (QV), the official database for all property transactions in New Zealand. The six selected cities were Auckland City, North Shore City, Waitakere City, Manukau City, Wellington City and Christchurch City. The primary reason for choosing these six cities was because of their significant weights on the overall New Zealand housing stock and large periodical sales volume. In total, there were 229,500 single family home sales used in the analysis for this research, over the period 1994 to 2004. During the time period from 1994 through 2004 the housing markets studied experienced periods of sudden house price falls, rapid price appreciation as well as price stagnation. For each city, house price movements were measured at both monthly and quarterly levels by using the SPAR and WRS methods, respectively.

For the estimation of the SPAR index for each local housing market, actual sale price less the value of chattels was used as “sale price” to form the SPAR ratios. Any ratio more than 2.4 or less than 0.4 was treated as an outlier and removed from the analysis.

This data cleaning process is in line with the method utilised by the official house price index published by QV.

As the repeat sales method is vulnerable to outliers (Meese and Wallace, 1997), all multiple sales where the second sale price is less than 0.7 or more than 2.5 times the first sale price were eliminated from the repeat sales analysis due to prior knowledge of the housing market price movement. Moreover, since the supplied QV data included building consent information for all the studied cities except for Auckland City[3], it was possible to further eliminate the quality changed repeat sales in this study. This minimised the constant quality problem faced by the standard repeat sales method.

Finally, the local housing market returns were estimated by using the log house price index differences over time on a continuous compounding basis.

5. Empirical Results

5.1 Autocorrelations

The results of testing for the autocorrelations of price changes are presented in Table 1 and 2. These showed house price index returns were highly correlated over time. The autocorrelation coefficients at various lags were large and the p-values associated with the Q-statistics were significant at the 5% level. Thus the null hypothesis of no autocorrelation was easily rejected. These results were very consistent as indicated by

[3] Building consent data is collected for revaluation purposes only where QV is the valuation service provider for the Council. For Auckland City, QV is not the valuation service provider for the council and for that reason there is no building consent data for Auckland City in the supplied data set.

both the SPAR and WRS indices. It was noticeable the house price returns were more inclined to show series correlation at the quarterly level rather than at the monthly level. For example, in North Shore City the autocorrelation for the lag of 4 quarters was estimated at 0.392 by the SPAR index in Table 1. This is compared to the result of 0.267 for the lag of 12 months by the SPAR index in Table 2. The difference can be explained as the quarterly index tends to smooth the price movements more than the monthly index does. Overall, the results implied local house price changes were persistent over time. That is historical house price movements are useful in forecasting the future price changes.

<Insert Table 1 and 2>

In order to confirm the serial correlations found in the above, we tested variance ratios of returns using the method proposed by Lo and MacKinlay (1988). The ratios were calculated by using overlapping periods of monthly or quarterly index returns. The results were presented in Table 3 and 4.

<Insert Table 3 and 4>

Table 3 Panel A showed the quarterly results for the SPAR index. The variance ratios were between 1.38 and 1.73 for a two-quarter return (Q=2) and increased for larger Z*(q). For example, the variance ratio of the North Shore City in panel A climbed from 1.73 (for q=2) to 5.12 (for q=8) with a Z*(q) of 8.99. Panel B represented the results for the WRS index. It showed a very similar pattern when compared to panel A. Similar results were also found in the monthly index returns as shown in Table 4.

Overall, the null hypothesis that the market risk structure grows linearly over time has been rejected. Returns were more inclined to correlate over a longer term than the shorter term.

When comparing indices used in the study, both the SPAR and WRS indices performed reasonably well. For most of the time, they delivered very similar results. One noticeable area of differences was that the SPAR index intended to be more serially correlated than the WRS index in both the autocorrelations and variance ratios analysis. This phenomenon may be due to the problem of the small sample size when building the index itself. Since the repeat sales index used only the repeated sales for index construction, the index itself was more subject to the sample selection bias and tended to contain more price noise than other indexing methods such as the SPAR methods, which used all market transactions.

In order to improve the estimate of how the market risk structure changes over time, we plotted the variance ratios of returns in Figure 1 and 2. Figure 1 showed the evolution of variance ratios based on the quarterly index returns, and Figure 2 represented the results based on the monthly index returns. For both figures, the linear form of risk structure was represented by a horizontal line called Randomwalk, and the quadratic form was represented by a 45 degree line called Quadratic. Clearly, the form of risk structure was dependent on the nature of local housing market. For example, in Figure 1 the risk structure of Wellington City was more likely to follow a linear form. On the other hand, all other cities including Auckland City and Christchurch City tended to follow a quadratic form. One explanation for this is the economic structure in Wellington housing market is quite different from other cities studied. Wellington is the capital of New Zealand and households in Wellington may differ in both behaviour and composition. For example, workers in Wellington City have the highest average wage in the country with a large percentage of them being government employees who are generally well educated and behave rationally. This may result in a relatively efficient nature of local housing market for Wellington.

It is interesting the observed quadratic form in Figure 1 did not grow without restriction. It appeared to last only for the first 8 quarters (2 years) and after that the actual risk form seemed to sit in between the linear and quadratic forms. When compared to the risk structure in Figure 2, it showed all cities were reasonably close to the linear form for the monthly measurement intervals. The findings have several implications for Case and Shiller's weighted repeated sales model. First, the assumption of using a linear form to down-weight the influence from sales with longer time intervals, is more likely to be true when producing the WRS index for a monthly reporting interval. Second, a quadratic form of risk structure as proposed by Lin and Liu (2008) appears to be more appropriate when estimating the WRS index for a quarterly level, but it is only correct for pair sales happened within a shorter time interval. A hybrid weighted procedure of combining both the linear and quadratic forms in the second step of WRS index could be a good alternative.

<Insert Figure 1 and 2>

6. Conclusions

This paper examined the serial persistence and risk structure for local housing markets. It was found the risk structure of local housing markets was specific to location differences and varied according different measurement intervals. For the quarterly measurement interval, the estimated market risk structure was more likely to follow a quadratic form, but only for a shorter time period of up to 8 quarters. For the monthly measurement interval, the market risk structure appeared to follow a linear form.

The findings imply the linear assumption of market risk structure used in step two of traditional WRS method may be too simple. A quadratic form could be considered as an alternative but only being appropriate for a shorter period of time. For a monthly produced WRS index, the issue of using a quadratic form was not important. Future research could be carried on whether the quarterly reported WRS index could be improved by a hybrid weighting system, which uses a quadratic form for sales with shorter time intervals and applies a linear form for sales with longer time intervals.

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Table 1: Autocorrelations of quarterly returns

City	Autocorrelation at lag 1	2	3	4	p-values Q2	Q4
			Panel A: SPAR Index			
North Shore City	0.659	0.418	0.365	0.392	(0.000)	(0.000)
Waitakere City	0.650	0.287	0.176	0.182	(0.000)	(0.000)
Auckland City	0.569	0.263	0.277	0.267	(0.000)	(0.000)
Manukau City	0.610	0.405	0.294	0.379	(0.000)	(0.000)
Wellington City	0.320	0.133	-0.141	-0.072	(0.062)	(0.149)
Christchurch City	0.649	0.532	0.480	0.457	(0.000)	(0.000)
			Panel B: WRS Index			
North Shore City	0.624	0.425	0.329	0.294	(0.000)	(0.000)
Waitakere City	0.650	0.345	0.297	0.295	(0.000)	(0.000)
Auckland City	0.534	0.299	0.236	0.229	(0.000)	(0.000)
Manukau City	0.560	0.348	0.330	0.213	(0.000)	(0.000)
Wellington City	0.308	0.199	0.144	-0.095	(0.045)	(0.105)
Christchurch City	0.815	0.738	0.542	0.444	(0.000)	(0.000)

Notes:

1. The figures presented are the autocorrelations up to and including that lag. P-values associated with the Q-statistics are presented in parentheses.
2. The quarterly return is calculated as the log difference between two consecutive quarterly prices. Sample period is from 1994:Q1 to 2004:Q4. Total sample size is 43.

Table 2: Autocorrelations of monthly returns

City	Autocorrelation at lag 1	2	3	4	5	6	12	p-values Q6	Q12
				Panel A: SPAR Index					
North Shore	0.108	0.345	0.219	0.228	0.203	0.138	0.267	(0.000)	(0.000)
Waitakere	0.309	0.372	0.223	0.159	0.170	0.088	0.149	(0.000)	(0.000)
Auckland	0.197	0.413	0.180	0.202	0.096	0.176	0.107	(0.000)	(0.000)
Manukau	-0.099	0.278	0.145	0.130	0.212	0.035	0.140	(0.001)	(0.001)
Wellington	-0.060	0.111	0.044	0.062	-0.007	0.052	-0.027	(0.768)	(0.768)
Christchurch	0.084	0.372	0.245	0.198	0.273	0.235	0.105	(0.000)	(0.000)
				Panel B: WRS Index					
North Shore	0.079	0.197	0.207	0.187	0.085	0.242	0.180	(0.000)	(0.000)
Waitakere	0.188	0.224	0.323	0.114	0.179	0.120	0.099	(0.000)	(0.000)
Auckland	0.072	0.177	0.192	0.143	0.079	0.027	0.096	(0.033)	(0.018)
Manukau	-0.179	0.073	0.179	-0.040	0.154	0.027	0.179	(0.043)	(0.023)
Wellington	-0.327	0.010	0.164	-0.014	-0.098	0.162	-0.042	(0.001)	(0.019)
Christchurch	0.130	0.245	0.259	0.285	0.339	0.264	0.140	(0.000)	(0.000)

Notes:

1. The figures presented are the autocorrelations up to and including that lag. P-values associated with the Q-statistics are presented in parentheses.
2. The monthly return is calculated as the log difference between two consecutive monthly prices. Sample period is from January, 1994 to December, 2004. Total sample size is 131.

Table 3: Variance ratios of quarterly returns

City	Quarterly price changes q=2	Z*(q)		q=4	Z*(q)		q=8	Z*(q)	
				Panel A: SPAR Index					
North Shore City	1.73	4.04	**	2.91	6.01	**	5.12	8.99	**
Waitakere City	1.69	3.63	**	2.50	4.65	**	4.08	6.87	**
Auckland City	1.60	3.74	**	2.37	4.75	**	4.12	7.27	**
Manukau City	1.68	3.44	**	2.80	5.35	**	5.02	8.31	**
Wellington City	1.38	2.44	**	1.78	2.78	**	2.04	2.39	**
Christchurch City	1.68	3.13	**	3.12	5.50	**	5.34	7.63	**
				Panel B: WRS Index					
North Shore City	1.69	4.17	**	2.82	6.01	**	4.89	8.89	**
Waitakere City	1.71	3.85	**	2.73	5.34	**	4.74	8.26	**
Auckland City	1.58	3.60	**	2.34	4.74	**	4.09	7.40	**
Manukau City	1.59	3.59	**	2.56	5.24	**	4.54	8.18	**
Wellington City	1.36	2.47	**	1.99	3.56	**	2.51	3.45	**
Christchurch City	1.90	3.65	**	3.66	6.08	**	5.87	8.05	**

Notes:

1. Column m represents the variance ratios of that overlapping q-period return, z(q) represents the standardized heteroskedasticity consistent test for that variance ratio. Under the random walk hypothesis, the value of the variance ratio should be equal to one. Sample period is from 1994:Q1 to 2004:Q4. Total sample size is 43.

** indicates statistical significant at the 0.05 level
* indicates statistical significant at the 0.10 level

Table 4: Variance ratios of monthly returns

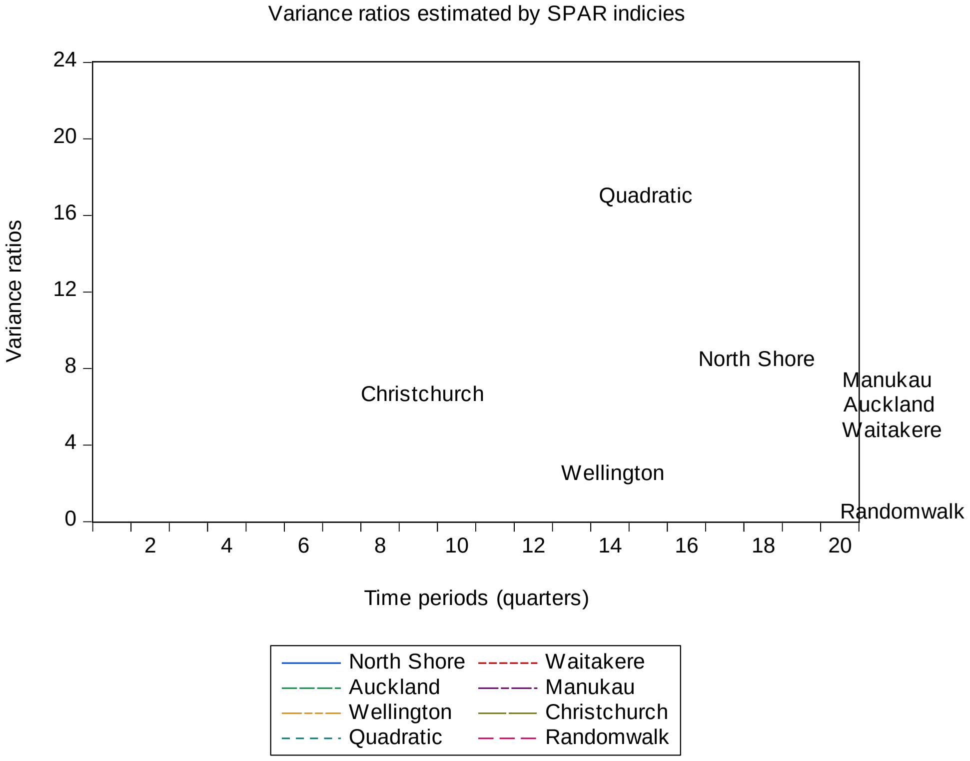
City	Monthly Returns m=2	Z*(q)		m=4	Z*(q)		m=8	Z*(q)		m=16	Z*(q)	
				Panel A: SPAR Index								
North Shore	1.12	1.64		1.68	4.42	**	2.71	6.63	**	4.58	9.23	**
Waitakere	1.33	3.47	**	2.03	5.62	**	2.87	6.66	**	4.18	8.09	**
Auckland	1.20	2.23	**	1.82	4.86	**	2.68	6.34	**	4.11	8.01	**
Manukau	0.91	-0.75		1.25	1.25		1.93	3.17	**	3.25	5.32	**
Wellington	0.95	-0.56		1.09	0.55		1.34	1.32		1.59	1.51	
Christchurch	1.10	0.83		1.69	3.24	**	2.81	5.68	**	4.90	8.57	**
				Panel B: WRS Index								
North Shore	1.08	0.69		1.45	2.17	**	2.21	4.05	**	3.67	6.61	**
Waitakere	1.19	2.03	**	1.73	4.16	**	2.62	5.92	**	4.24	8.32	**
Auckland	1.07	0.85		1.37	2.35	**	1.89	3.52	**	2.86	5.01	**
Manukau	0.83	-2.02	**	0.92	-0.51		1.15	0.58		1.81	2.16	**
Wellington	0.68	-3.67	**	0.63	-2.28	**	0.70	-1.15		0.91	-0.25	
Christchurch	1.15	1.35		1.64	3.30	**	2.91	6.48	**	5.31	10.33	**

Notes:

1. Column m represents the variance ratios of that overlapping q-period returns, z(q) represents the standardized heteroskedasticity-consistent test for that variance ratios. Under the random walk hypothesis, the value of the variance ratio should be equal to one. The monthly return is calculated as the log difference between two consecutive monthly prices. Sample period is from January, 1994 to December, 2004. Total sample size is 131.

** indicates statistical significance at the 0.05 level
* indicates statistical significance at the 0.10 level

Figure 1: Market risk structure estimated at the quarterly measurement intervals



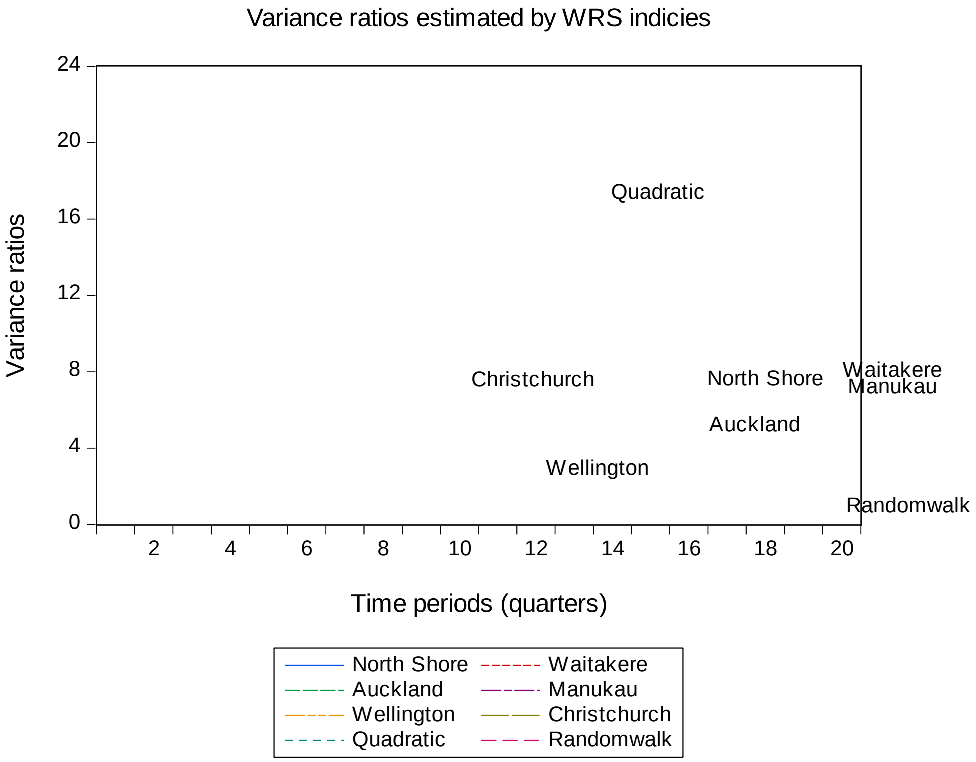


Figure 2: Market risk structure estimated at the monthly measurement intervals