# How High A Hedge Is High Enough? An Empirical Test of NZSE10 Futures.


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## Abstract

Undoubtedly, for risk adverse equity investors, a major use of a futures market is risk reduction, but hedging often incurs additional risk. An investor will only be protected if the payoff from their futures position is exactly opposite to the payoff from their equity position. A number of different methods have been suggested to determine the 'optimal' hedge ratio and in this study four alternative methods are empirically tested. These are the naïve hedge ratio of one to one, the regression model, the traditional method where the hedge ratio is the product of the coefficient of correlation and the ratio of the standard deviations of the two series and the co-integration approach in which the hedge ratio is developed from the Error Correction Model (ECM).

Each method is used to calculate the size of the short three-month hedge required in the NZSE10 Futures to protect an investor's long position in the NZSE 10 Index or TeNZ Fund beginning in July 1996. The test is repeatedly quarterly until September 2001 with the payoffs from each method being tested to determine if they are statistically different from zero. As the purpose of hedging is risk reduction any strategy that yields a payoff different from zero is considered to be sub optimal.

Our results show that, in hedging the NZSE10 Index, payoffs to the naïve, regression and traditional hedges were statistically different from zero. While we were unable to show that the average payoff from the ECM method were different to zero the large standard deviation of payoff from this method would suggest it to be a risky hedging strategy. Similarly investors wishing to hedge a TeNZ position face payoffs with large standard deviations, largely due in this case to tracking error between the TeNZ Fund and the underlying index.



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# Introduction

Hedging is one of the main purposes for trading in futures markets. How to find the optimal hedge ratio is important for investors wanting to hedge their positions, in the underlying markets, as either under or over hedging their positions can be damaging. In theory, if the futures price mirrors the spot prices perfectly, the hedge ratio will be one, which we call the Naïve Hedge. This strategy will only work well when the futures price moves exactly the same as the underlying asset, otherwise, investors might either be over or under hedged. By adopting this hedging strategy the hedger has equal but opposite spot and futures positions. But many empirical studies have shown that the spot and futures price have parallel but not exactly identical movements.

Studies such as those of Ederington (1979), and Hill and Schneeweis (1982) showed that a simple regression model, which regressed the previous returns in the spot market on the respective futures markets, could estimate the hedge ratio. Using the regression equation in the form of:

**Equation 1**

$$S_t = \alpha_0 + \alpha_1 F_t + \varepsilon_t$$

the coefficient factor $\alpha_1$ will be what we call the Regression Hedge. However, one problem is that the simple regression model considers that the hedge ratio is constant over time, but this has been found to not always be the case.

Hull (1997) suggests that as the objective of the hedger is to minimize risk, the optimal hedge ratio is the product of the coefficient of correlation between the change in the spot price, the change in the futures price and the ratio of the standard deviation of the change in spot price to the standard deviation of the change in futures price. It shows that the optimal hedge ratio does not have to be one. This method we call the Traditional Hedge, calculated from:

**Equation 2**

$$h = \rho \frac{\sigma_s}{\sigma_F}$$

Instead of using a simple regression model or the traditional method, Granger (1981) developed a time-varying approach called Co-Integration. This focuses on modelling the long run equilibrium relationships in two or more time series while also allowing for their short-term dynamics. Engle and Granger (1987) show that if two series are non-stationary but a linear combination of them is stationary, the two series are co-integrated and there must exist an error correction representation. Kroner and Sultan (1993) have shown that regression model given before is mis-specified because it ignores the short-rum dynamics or the error correction term. Therefore, hedge ration developed by simple regression model is unreliable. Thus we use the error correction model (ECM) developed from co-integration theory to derive the ECM Hedge.

If we assume two variables say X and Y are both I(1) then it is normally true that a linear combination of the two variables will also be I(1) (Holden and Thompson 1992). However, in some circumstances a linear combination of two I(1) variables will result in a variable which is I(0) and in this instance the two variables are said to be co-integrated (Holden and Thompson 1992). More formally if Y and X are both I(1) and u in equation 1 is I(0) then Y and X are said to be co-integrated. Here λ is said to be the constant of co-integration and, in the case of more than two variables, it becomes the co-integrating vector.

**Equation 3**

$$ut = Y_t - \boldsymbol{l}$$

Granger (1986) and Engle and Granger (1987) have demonstrated that if Y and X are both I(1) variables and are co-integrated, an error correction model exists.

The error correction model may exist of following form:

**Equation 4**

$$\Delta Y_t = -p_1 u_{t-1} + lagged\,(\Delta Y, \Delta X) + \boldsymbol{e}_{1t}$$

**Equation 5**

$$\Delta X_t = -p_1 2 u_{t-1} + lagged\,(\Delta Y, \Delta X) + \boldsymbol{e}_{2t}$$

with

**Equation 6**

$$|p_1| + |p_2| \neq 0$$

where $u_{t-1}$ is the error lagged one period derived from the co-integrating regression given by (1) and $\varepsilon_{it}$ are the two error terms which may be correlated or exhibit autocorrelation.

More specifically in our situation, we could get an error correction model for NZSE10 index and index futures, which takes the form of:

**Equation 7**

$$\Delta S_t = \alpha_0 + \alpha_1 \Delta F_t + \alpha_2 \Delta S_{t-1} - pu_{t-1} + \varepsilon_{2t}$$

Note the number of the lagged value of ΔS and ΔF put into the right hand of equation 7 is determined by the Akaike's Information Criterion (AIC) in order to allow the residual from equation 7 to be white noise. Thus the value of the coefficient of $\alpha_1$ will be the hedge ratio.

Wilkinson, Rose and Young (1999) apply co-integration methodology to produce the hedge ratio for the New Zealand and Australian 90-Day, 3-Year and 10-Year debt and futures markets. They compare traditional methods of calculating hedge ratios with those computed by using univariate and multivariate ECMs, then use out-of-sample forecasting to determine which approach is the most effective one. Their results show that the ECMS do not outperform the more traditional methods of hedging.

However, Chou and Denis (1996) estimates and compares the hedge ratios of the conventional and the ECM using Japan's Nikkei stock average (NSA) index and the NSA index futures with different time intervals. Comparisons of out of sample hedging performance reveal that the ECM outperforms the conventional model, suggesting that the hedge ratios obtained from ECM will reduce the risk when hedging.

Gonzalez, Powell and Stump (1998) found that large well-informed investors are using TeNZ to exploit their information advantages ahead of the market. This suggests they might somehow use the NZSE10 index futures to hedge their positions in TeNZ (or NZSE10 index). Zou and Pinfold (2001) suggest that NZSE10 index, NZSE10 index futures and TeNZ are stationary in their first difference and they form a co-integration relation, thus we are able to perform the co-integration analysis and develop an Error Correction Model in order to get a hedge ratio from the ECM.

## Testable Hypotheses

Hedgers are seeking risk reduction they are not seeking to directly profit from their futures position if that was their objective they would be classified as speculators. Therefore, the aim of this study is to determine the hedging strategy that results in a zero payoff to investors holding a long position in the NZSE10 Index spot market or TeNZ Fund. Four hypotheses follow from our study's aim, they are:

Hypothesis 1: The payoff from a naïve hedge ratio is not statistically different from zero.

Hypothesis 2: The payoff from the regression hedge ratio is not statistically different from zero.

Hypothesis 3: The payoff from a traditional hedge ratio is not statistically different from zero.

Hypothesis 4: The payoff from a co-integration hedge ratio is not statistically difference from zero.

The alternative hypothesis for each of the above is that the payoff is statistically different from zero.

## Research Data and Methodology

In order to facilitate testing a number of assumptions are made by the researchers,

1. The cost of holding a long position in the market is exactly countered by dividend payments received,
2. The short position in the futures market doesn't incur any transaction costs or require any margin to be advanced by the investor,
3. Margin contracts are infinitely divisible.

While investors in the "real world" obviously do not enjoy these assumptions their affect is expected to be similar for all four strategies. They are applied because their adoption considerably simplifies the research while being consistent with an investor's objective of risk reduction, rather than profit maximisation.

At a later date the researchers intend to relax these assumptions in order to judge the cost to an investor of optimal protection.

The data used in this study was the daily closing prices for NZSE10 index, TeNZ fund, and daily settlement price for NZSE10 index futures, for the period between July 1, 1996 and Sept. 30, 2001. All data was collected from Datastream.

An investment strategy was developed where a long position in the NZSE 10 index was hedged by a short position in the NZSE 10 index futures. This position was held for three months, which is the life of the futures contract, at which point it was reversed. The payoff of this strategy was calculated as:

**Equation 8**

$$Payoff = -SpotIndex_0 + (h * Futures_0) + SpotIndex_3 - (h * Futures_3)$$

with the expectation being that this should be approximately equal to zero if the hedge ratio ($h$) is correctly specified.

The TeNZ fund is designed to mimic the NZSE 10 index and offers investors the opportunity to indirectly invest in the NZSE 10 index, without the onerous task of continually rebalancing their portfolio. However, investors in the TeNZ fund face the problem of tracking area, where the TeNZ fund does not exactly match the underlying index. For this reason the payoff was calculated for a TeNZ investor as:

**Equation 9**

$$Payoff = -SpotTeNZ_0 + (h * Futures_0) + SpotTeNZ_3 - (h * Futures_3)$$

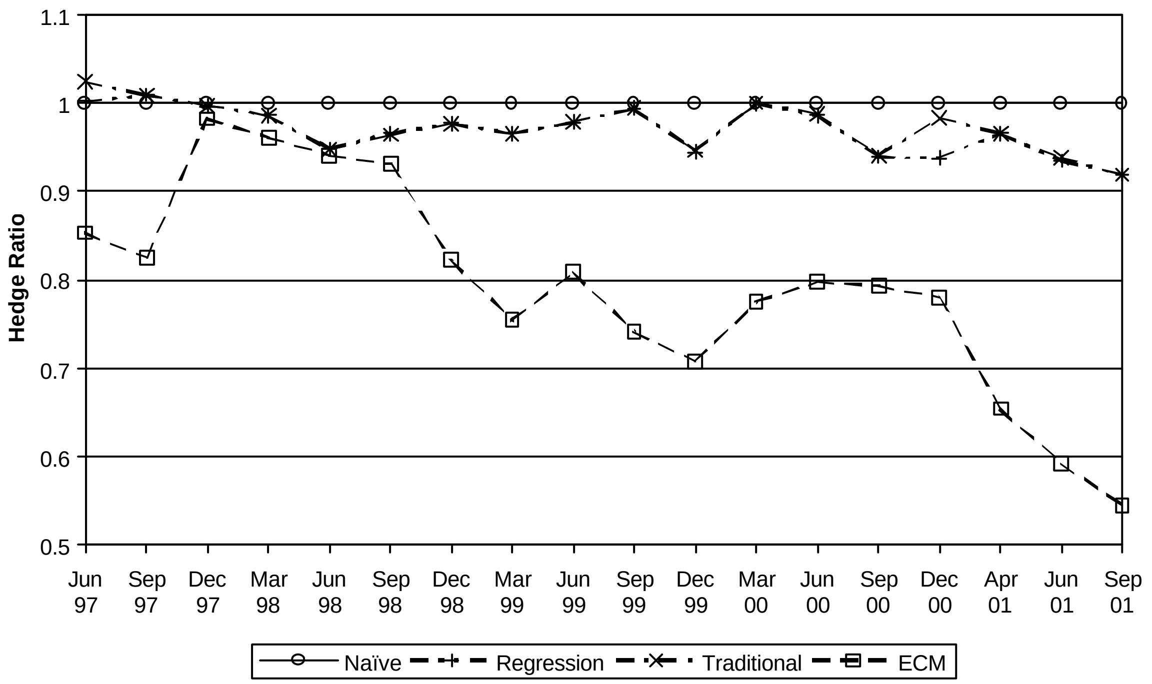
The hedge ratio used to calculate this payoff was the same as the hedge ratio used to calculate the payoff from the NZSE10 index investment.

The payoff from equations 8 & 9 is for one unit of the NZSE10 Index or TeNZ Fund, which are nominally $1000. Therefore as an example a payoff of +10 would mean that an investor would be better off by $10 at the end of the three month period.

## Hedge Ratios

One years worth of NZSE10 index and NZSE10 index futures data (250 daily observations) was used to calculate hedge ratios using the traditional, regression and ECM methods (the naïve hedge ratio was always one). With the first estimation period ending on the 27$^{th}$ June 97 and then being repeated at three monthly intervals until the 27 September 01, giving 18 estimations of each hedge ratio. Appendix 1 shows the hedge ratios derived from the four alternative hedging strategies starting from the 1st July 1996 to 27th September 2001.

**Figure 1 Alternative Hedge Ratios**



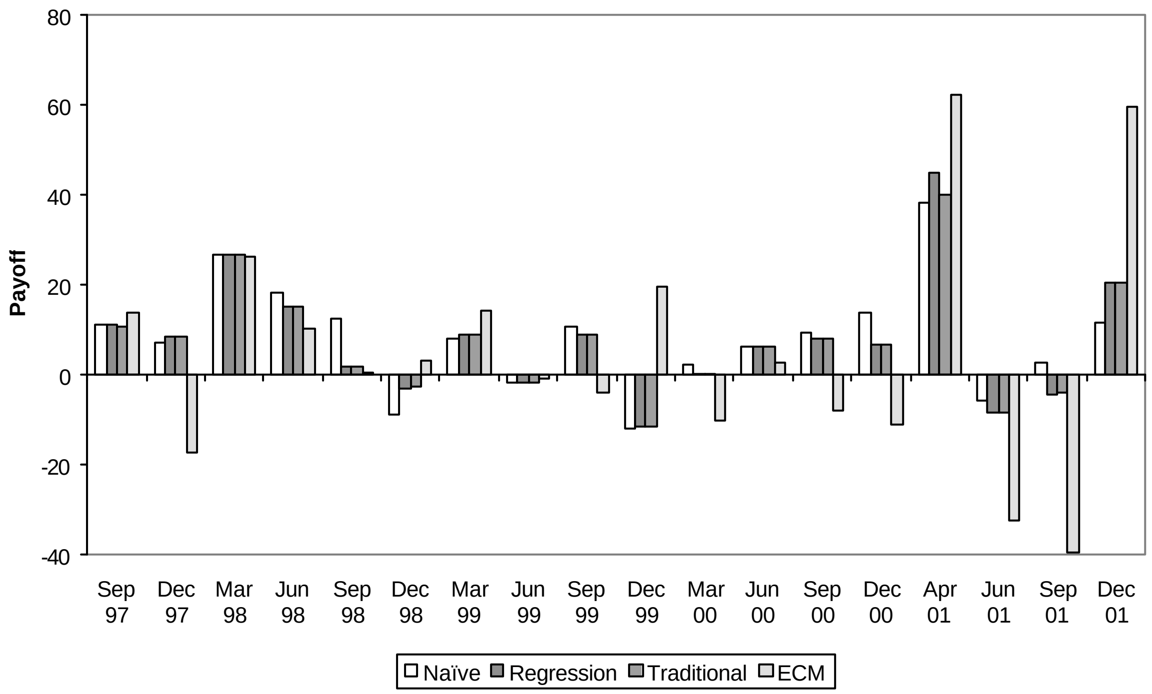

Plotting the hedge ratios for these four methods in the figure 1 shows that the ECM method yields the lowest hedge ratios in all estimation periods, with the simple regression and traditional methods have a relative higher hedge (the naïve hedge is of course constant at one). Almost all of the hedge ratios derived from these three methods are below one, indicating that when hedging a long position in the spot market, one needs less than one short position in the futures market.

## NZSE10 Index Payoff

Payoffs were calculated for each hedging method (Appendix 2), and then plotted below. Preliminary inspection shows that the payoffs from most of the four hedging methods are positive although it is immediately apparent that they are more volatile in 2001.

The first three hedging methods: naïve, regression and traditional, have very similar results being either all positive or all negative. Payoff to the ECM hedging strategy is generally larger than for the other three methods (either more positive or more negative) and is often negative when the other methods are positive and vice versa.

**Figure 2 Alternative Payoffs to NZSE10 Index Hedge**




The means of all four strategies were calculated and tested to see if they were statistically different from zero. As expected all four were positive with the ECM method being the lowest at 5.080. The means of the naïve, regression and traditional were significant with T-statistics greater than 2.487 but examination of their 95% confidence intervals showed that none contained zero, indicating that we should reject the hypothesis that payoffs from these strategies were not statistically different from zero.

**Table 1 One-Sample Test – Mean NZSE10 Index Payoff**

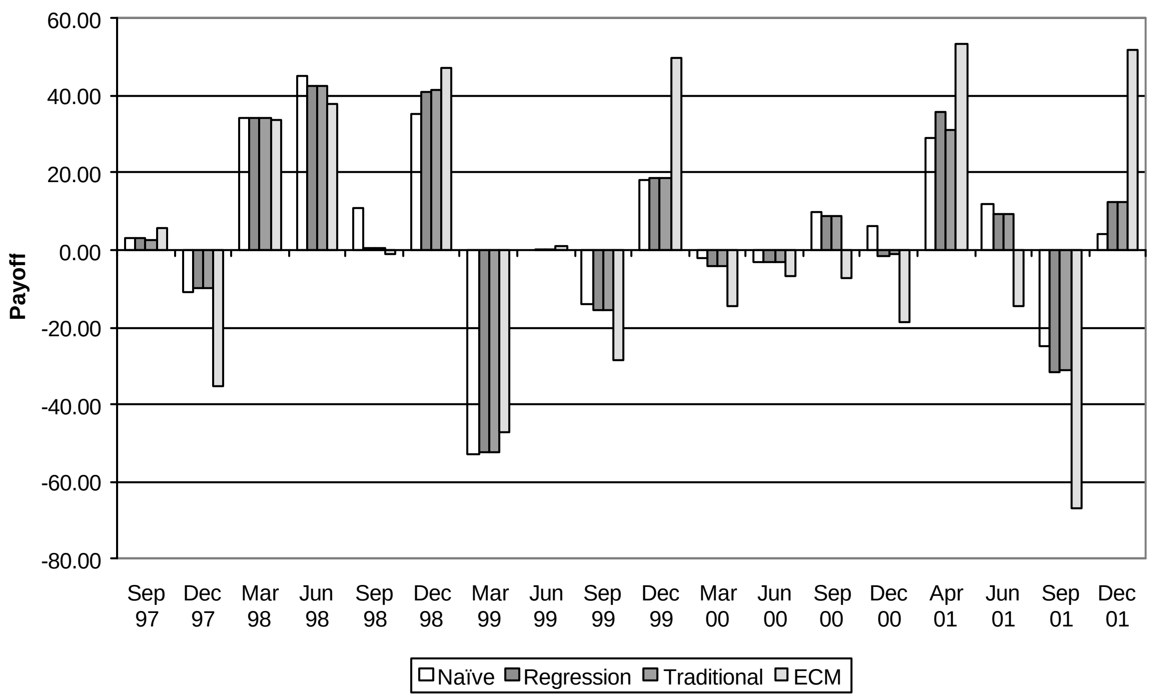
| Test Value = 0 | Mean | t | Std Dev | Sig. 2-tailed | 95% Confidence Interval Lower | Upper |
|---|---|---|---|---|---|---|
| Naïve | 8.426 | 2.964 | 12.057 | 0.009 | 2.429 | 14.423 |
| Regression | 7.821 | 2.487 | 13.339 | 0.024 | 1.187 | 14.454 |
| Traditional | 7.576 | 2.569 | 12.514 | 0.020 | 1.353 | 13.800 |
| ECM | 5.080 | 0.821 | 26.244 | 0.423 | -7.971 | 18.131 |

The confidence interval for the ECM hedging strategy did however contain zero, but the payoffs from this strategy resulted in a standard deviation of 26.244, which was double that of any of the other hedging strategies. The consequence of this larger standard deviation was that the confidence interval was also considerably wider, and whilst it is not possible to say that the true mean is not zero, the high standard deviation makes for a risky hedging strategy.

## TeNZ Payoff

The hedge ratios previously developed were then applied (using the same methodology that looked to the relationship between the NZSE Futures and the NZSE10 Index rather than the TeNZ Fund) to a long investment in the TeNZ fund and the payoffs calculated (Appendix 3).

**Figure 3 Alternative Payoffs to TeNZ Fund Hedge**




Examination of the above plot suggests similar results for each hedging strategy although it does appear that payoffs to the ECM hedge become more extreme towards the end of the testing period.

Calculating the means show that these are lower than the respective payoff means for the NZSE10 Index hedge. Again the ECM hedge had the lowest at 2.154 of all four hedging methods.

**Table 2 One-Sample Test – Mean TeNZ Fund Payoff**

| Test Value = 0 | Mean | t | Std Dev | Sig. 2-tailed | 95% Confidence Interval Lower | Upper |
|---|---|---|---|---|---|---|
| Naïve | 5.500 | 1.002 | 23.284 | 0.330 | -6.079 | 17.079 |
| Regression | 4.895 | 0.846 | 24.557 | 0.410 | -7.317 | 17.107 |
| Traditional | 4.650 | 0.815 | 24.211 | 0.426 | -7.389 | 16.690 |
| ECM | 2.154 | 0.252 | 36.199 | 0.804 | -15.847 | 20.156 |

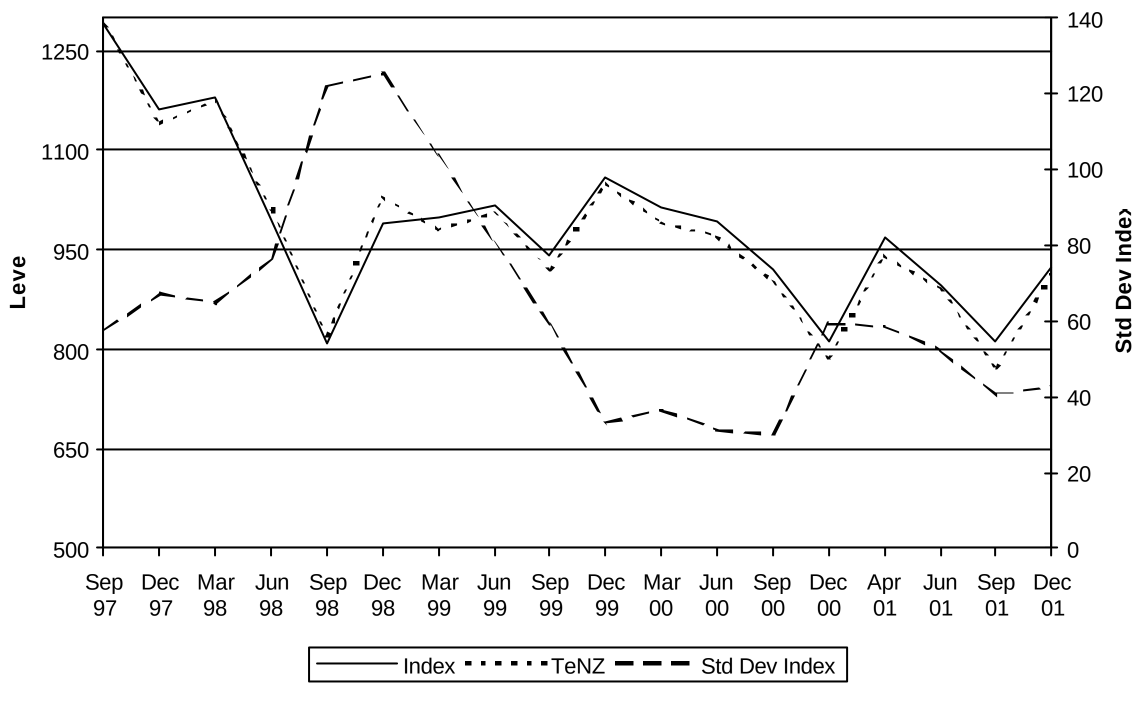
All four confidence intervals contained zero, but this again was due to the wider confidence intervals as a result of the increased standard deviations of each payoff mean, with the standard deviation of the ECM hedge being the greatest at 36.199.

## Conclusion

The results obtained in this research raise serious problems for investors wishing to hedge their exposure to either the NZSE10 Index or TeNZ Fund. The high standard deviations calculated for the payoffs for all strategies suggest that rather than reducing risk they could in fact be increasing the risk they face.

Looking first at the problems associated with hedging a position in the TeNZ Fund it seems likely that tracking error between the TeNZ Fund and the NZSE10 Index is the cause of increased variability of payoffs to the TeNZ hedges over their respective NZSE10 Index hedges. Figure 4 below shows that the TeNZ Fund has traded at a discount to the NZSE10 Index since the beginning of 1999. Because of this tracking error it is not practical to use the NZSE10 Futures to hedge a position in the TeNZ Fund.

**Figure 4 NZSE10 Index, TeNZ Fund and Index Std Dev**



Investors hedging their positions in the NZSE10 index also face highly variable payoffs to all hedging strategies. Of particular concern are the payoffs to hedges in each quarter of 2001 that appear to contribute to most of the increased variability of payoffs. In this period the hedge ratio for the ECM dropped steadily from 0.7806 in December 2000 to 0.5458 in September 2001. In looking for a possible explanation consideration was given to what was happening to the NZSE10 Index. Looking at Figure 4 it can be seen that over this period the index traded in a range of 150 points from a low of 800 to just above 950 points. While this is quite low it is no worse than the low that the index reached in September 98 a period when payoffs to all hedging strategies were relatively low.

A second reason that was considered was the volatility of the NZSE10 Index in this period, so the standard deviations of the index that were used in calculating the traditional hedge were examined. These standard deviations are of the index for the preceding 250 days and are plotted in figure 4 above. The standard deviation of the index reached a high in December 1998 before falling to its low points in 2000 and while standard deviations were higher in 2001 there is nothing to suggest that they affected the payoffs to the hedging strategies.

At this stage the researchers have no credible explanation for the poor performance of the ECM, but the intention is to repeat the testing using a monthly rolling hedge rather than a quarterly hedge, a longer estimation period for the ECM going back at least two years and to include some information variables in the ECM. The only comfort that can now be offered to hedgers is at least the mean payoffs to the hedging strategies were not negative.

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# Appendicies

**Appendix 1 Alternative Hedge Ratios**

| Hedge Date | Naïve | Regression | Traditional | ECM |
|---|---|---|---|---|
| Jun 97 | 1 | 1.0017 | 1.0244 | 0.8536 |
| Sep 97 | 1 | 1.0091 | 1.0090 | 0.8248 |
| Dec 97 | 1 | 0.9971 | 0.9969 | 0.9825 |
| Mar 98 | 1 | 0.9861 | 0.9861 | 0.9613 |
| Jun 98 | 1 | 0.9485 | 0.9475 | 0.9411 |
| Sep 98 | 1 | 0.9662 | 0.9643 | 0.9311 |
| Dec 98 | 1 | 0.9774 | 0.9768 | 0.8231 |
| Mar 99 | 1 | 0.9658 | 0.9653 | 0.7549 |
| Jun 99 | 1 | 0.9785 | 0.9784 | 0.8095 |
| Sep 99 | 1 | 0.9941 | 0.9941 | 0.7418 |
| Dec 99 | 1 | 0.9448 | 0.9460 | 0.7078 |
| Mar 00 | 1 | 0.9994 | 1.0007 | 0.7754 |
| Jun 00 | 1 | 0.9862 | 0.9879 | 0.7978 |
| Sep 00 | 1 | 0.9390 | 0.9409 | 0.7936 |
| Dec 00 | 1 | 0.9382 | 0.9833 | 0.7806 |
| Apr 01 | 1 | 0.9654 | 0.9654 | 0.6548 |
| Jun 01 | 1 | 0.9348 | 0.9384 | 0.5932 |
| Sep 01 | 1 | 0.9188 | 0.9189 | 0.5458 |

**Appendix 2 Alternative Payoffs to NZSE10 Index Hedge**

| Payoff Date | Naïve | Regression | Traditional | ECM |
|---|---|---|---|---|
| Sep 97 | 11.24 | 11.21 | 10.83 | 13.73 |
| Dec 97 | 7.32 | 8.58 | 8.58 | -17.03 |
| Mar 98 | 26.67 | 26.61 | 26.61 | 26.32 |
| Jun 98 | 18.10 | 15.39 | 15.39 | 10.55 |
| Sep 98 | 12.42 | 2.07 | 1.87 | 0.58 |
| Dec 98 | -8.93 | -3.02 | -2.67 | 3.13 |
| Mar 99 | 8.30 | 9.05 | 9.07 | 14.14 |
| Jun 99 | -1.83 | -1.66 | -1.66 | -0.60 |
| Sep 99 | 10.79 | 9.16 | 9.15 | -3.69 |
| Dec 99 | -11.94 | -11.22 | -11.22 | 19.56 |
| Mar 00 | 2.51 | 0.14 | 0.19 | -10.05 |
| Jun 00 | 6.53 | 6.52 | 6.54 | 2.94 |
| Sep 00 | 9.35 | 8.18 | 8.32 | -7.84 |
| Dec 00 | 14.01 | 6.69 | 6.92 | -10.76 |
| Apr 01 | 38.15 | 44.95 | 39.99 | 62.28 |
| Jun 01 | -5.53 | -8.19 | -8.19 | -32.11 |
| Sep 01 | 2.65 | -4.07 | -3.69 | -39.25 |
| Dec 01 | 11.86 | 20.39 | 20.38 | 59.55 |
| Mean | 8.43 | 7.82 | 7.58 | 5.08 |
| Std Dev | 12.06 | 13.34 | 12.51 | 26.24 |

**Appendix 3 Alternative Payoffs to TeNZ Hedge**

| Payoff Date | Naïve | Regression | Traditional | ECM |
|---|---|---|---|---|
| Sep 97 | 3.00 | 2.97 | 2.59 | 5.49 |
| Dec 97 | -11.00 | -9.74 | -9.74 | -35.35 |
| Mar 98 | 34.00 | 33.94 | 33.94 | 33.65 |
| Jun 98 | 45.00 | 42.29 | 42.29 | 37.45 |
| Sep 98 | 11.00 | 0.65 | 0.45 | -0.84 |
| Dec 98 | 35.00 | 40.92 | 41.26 | 47.06 |
| Mar 99 | -53.00 | -52.25 | -52.23 | -47.16 |
| Jun 99 | 0.00 | 0.17 | 0.17 | 1.23 |
| Sep 99 | -14.00 | -15.63 | -15.64 | -28.48 |
| Dec 99 | 18.00 | 18.72 | 18.72 | 49.50 |
| Mar 00 | -2.00 | -4.37 | -4.32 | -14.56 |
| Jun 00 | -3.00 | -3.01 | -2.99 | -6.59 |
| Sep 00 | 10.00 | 8.83 | 8.97 | -7.19 |
| Dec 00 | 6.00 | -1.32 | -1.09 | -18.77 |
| Apr 01 | 29.00 | 35.80 | 30.84 | 53.13 |
| Jun 01 | 12.00 | 9.34 | 9.34 | -14.58 |
| Sep 01 | -25.00 | -31.72 | -31.34 | -66.90 |
| Dec 01 | 4.00 | 12.53 | 12.52 | 51.69 |
| | | | | |
| TeNZ Payoff | | | | |
| Mean | 5.50 | 4.89 | 4.65 | 2.15 |
| Std Dev | 23.28 | 24.56 | 24.21 | 36.20 |