FACTORS AFFECTING T-BOND HEDGE RATIO INSTABILITY

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ABSTRACT

Unstable hedge ratios can adversely affect the measure of hedging effectiveness in the regression approach to minimize risk. This paper examines the relative importance of the correlation coefficient versus the standard deviation ratio as the cause of unstable hedge ratios using T-bond futures. The paper concludes that the standard deviation ratio is significantly more important than the correlation coefficient in determining changes in the hedge ratio for the Bellwether series, while both the standard deviation ratio and the correlation coefficient are important for the two-year T-note series. These results have implications for forecasting and analyzing hedge ratios when the hedge ratios are unstable over time.

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I. Introduction

Since the introduction of interest rate futures contracts in 1975, hedging has generated interest in both the academic and practitioner communities, while also serving as the traditional rational for organized futures markets. Applying portfolio theory to the problem of hedging, Ederington (1979) derives a model which defines the minimum variance hedge ratio (HR) as the proportion of futures to spot positions that minimizes price change risk. Since that time a substantial number of theoretical and empirical research articles have been undertaken which examine hedging techniques and the performance of these techniques.[1] However, research involving this portfolio (regression) model has assumed that the hedge ratio is stable over time, i.e. the hedge ratio and hedging effectiveness measures derived by employing data from time period "t" are deemed to be the relevant measures for hedging purposes in period "t+1".

This paper begins by illustrating how an unstable hedge ratio creates an upward bias in the traditional R^2 measure of hedging effectiveness. If unstable hedge ratios adversely affect hedging effectiveness, then an analysis of the two factors that determine the hedge ratio, the correlation coefficient (CORR) and the standard deviation ratio (SDR) are useful. Finally, the association of these factors to the characteristics of the bond series is discussed.

II. The Minimum Variance Hedge Ratio Model

A. The Basic Model

The minimum variance hedge ratio model assumes that the hedger desires to minimize the variance of the price changes of the hedged position. As developed by Ederington (1979), the expected return on a hedge position is defined as:

$$E(R) = X_S\ E[S_{t+k} - S_t] + X_F\ E[F_{t+k} - F_t] \qquad (1)$$

Where:

X_S = spot holdings (assumed fixed)

S_t = spot price at time t

X_F = futures market position

F_t = futures price at time t

k = the length of the hedge.

The risk of the position then is defined in terms of the variance in the return, var(R):

$$\mathrm{var}(R) = X_S^2\,\sigma_S^2 + X_F^2\,\sigma_F^2 + 2X_S\,X_F\,\sigma_{SF} \qquad (2)$$

Where:

σ_S^2 and σ_F^2 = the variances of the spot and futures price changes

σ_{SF} = the covariance between the spot and futures price changes, between times t and t+k.

Substituting the hedge position $b = -X_F/X_S$ into equation (2) and rearranging, one obtains:

$$\mathrm{var}(R) = X_S^2\,\{\sigma_S^2 + b^2\,\sigma_F^2 - 2b\sigma_{SF}\}. \qquad (3)$$

Taking the partial derivative of var(R) with respect to b, setting the equation equal to zero and solving for b, one obtains the minimum variance hedge ratio (HR), b^*:[2]

$$b^* = \sigma_{SF}/\sigma_F^2 \qquad (4)$$

Or, alternatively, if we want to determine the individual factors affecting the hedge ratio we employ:

$$b^* = \rho_{SF}\,\sigma_S\,\sigma_F/\sigma_F^2$$

$$= \rho_{SF}(\sigma_S/\sigma_F) \qquad (5)$$

Where:

ρ_{SF} = correlation between the spot and futures price changes (CORR)

σ_S/σ_F = the standard deviation ratio (SDR).

The coefficient of determination, $\rho^2 = R^2$, is employed to determine the <u>ex-post</u> proportion of the variability of the spot price changes that can be hedged successfully by employing the minimum variance hedge ratio, b^*. However, using this procedure to obtain the hedge ratio and to measure the hedging effectiveness assumes that b^* is invariant over time. In reality, b^* can change over time due to economic and statistical considerations, creating additional risk in the hedge position because of a non-optimal hedge ratio between futures and cash.

B. <u>The Effect of Unstable Hedge Ratios</u>

The effect of unstable hedge ratios on measuring hedging effectiveness is shown by examining basis risk. The basis resulting from an <u>ex-post</u> hedged position during time period t+1 is defined in terms of the minimum variance hedge by (6):

$$H_{t+1} = \text{Basis} = S_{t+1} - b_{t+1}\,F_{t+1} \qquad (6)$$

Defining our <u>ex-ante</u> hedge ratio as the previous period's hedge ratio we obtain:

$$b_t = b_{t+1} - \Delta b_t \tag{7}$$

Consequently, the change in the basis, including the effect of employing the previous period's hedge ratio b_t as an estimate of the true current period's hedge ratio b_{t+1}, is found by substituting b_t from (7) for b_{t+1} from (6):

$$\Delta \text{Basis} = \Delta H_{t+1} = \Delta S_{t+1} - (b_{t+1} - \Delta b_t)\, \Delta F_{t+1} \tag{8}$$

Using R^2 as the measure of hedging effectiveness, equation (9) reformulates this definition in terms of the variability in the basis, i.e. basis risk, by employing the hedged (H) and unhedged (S) (cash) variability:

$$R^2 = 1 - \Sigma(\Delta H - \overline{\Delta H})^2 / \Sigma(\Delta S - \overline{\Delta S})^2$$

$$= 1 - (\text{Basis Risk/Total Spot Risk}) \tag{9}$$

In (9) the squared price change differences are summed over the time intervals chosen to measure risk during time period t+1.

If we define R_{t+1}^2 as the ex-post hedging effectiveness from using b_{t+1} with data from t+1, and R_t^2 as the ex-ante hedging effectiveness from using b_t with data from t+1, then the upward bias in the ex-post R^2 value when hedge ratios are unstable is determined by finding $\Delta R^2 = R_{t+1}^2 - R_t^2$. Consequently, using the hedge ratio from the previous period, when hedge ratios are unstable over time, results in an upward biased R^2 value for hedging effectiveness. Conceptually, if b_{t+1} is the minimum variance hedge ratio during time t+1, then any other hedge ratio b_t that has a different slope to the regression line will have a larger sum of squared errors and thus a lower R^2 value.

III. Significance of Unstable Hedge Ratios

Section II discusses how using the ex-post minimum variance hedge ratio b_{t+1} to determine R_{t+1}^2 for time period "t+1" creates an upward biased estimate of the hedging effectiveness when the hedge ratio b_t is unstable over time and this hedge ratio is employed in time period t+1 to determine the ex-ante R_t^2. Since the ex-post R_{t+1}^2 values are employed in previous research to determine the hedging effectiveness, the implications of the above result need to be examined. The following issues are important for hedging applications which are related to the potential bias in the hedging effectiveness:

- Are hedge ratios unstable, and if so then to what extent do they vary?
- If hedge ratios are unstable then can this instability be associated more closely with changes in the correlation coefficient (CORR) factor or changes in the standard deviation ratio (SDR) factor?
- To what extent can the above factor variability be associated with characteristics of the underlying asset, for example the liquidity, maturity, and coupon characteristics of bonds?

- What implications exist for the hedger if hedge ratios are unstable and we can identify the characteristics associated with this instability?

The empirical results for the two series of T-bond hedges given later in this paper show that on average the hedge ratios vary by 10% to 12% per quarter, with some quarters having changes of 35% or more. This variability is large enough to examine the factors that create this instability. Thus, the paper examines whether changes in correlation (CORR) or the standard deviation ratio (SDR) can be more closely associated with the unstable hedge ratios. The discussion also relates the association of the bond characteristics with the variability in these factors.

This paper documents the instability in the hedge ratio for two T-bond series and examines which of the two factors that determine b^* in equation (4) has the greater affect on this instability of the hedge ratio. Characteristics of the individual bond series are related to these two factors to show the relationships involved.

IV. Data and Methodology

The hedge ratios, correlations, and SDRs examined in this study are computed from spot and futures price changes for the period 1/79 through 12/90. Cash positions for both the Bellwether T-bond series and two-year T-notes are employed in the analysis in relation to the nearby T-bond futures contract.[3] Hedge ratios are determined on a quarterly basis by employing weekly futures and cash price changes. Prices from the last trade of the week, typically Friday, are used to generate the weekly price changes. This data provides forty eight quarters of data to generate the results in this paper.[4]

The analysis begins by documenting the hedge ratio instability. The normality of the variables then is examined by employing the ratio of the range to the sample standard deviation, often called the studentized range (SR). The appropriate parametric and nonparametric tests are then performed on the sample means, standard deviations, and ranks to determine the existence of statistically significant differences between the variables. Finally, linear regression relationships between the variables are examined.

V. Results

A. Hedge Ratio Instability

The hedge ratios, correlations, and SDRs using the quarterly data for the nearby contract, along with the quarterly changes for these variables, appear in Table 1A for the Bellwether T-bond and Table 1B for the two-year T-note. The differing characteristics of the Bellwether series and the two-year note provide different results for the hedge ratios, correlations, and standard deviation ratios. In particular, the correlation values for the Bellwether bonds are consistently high, with ρ values ranging from 83.0 to 99.7; the correlations for the two-year notes are lower, ranging from 18.1 to 96.8. The very high correlation values for the Bellwether series relates to the liquidity of these newly issued bonds and the fact they are typically hedged with T-bond futures by the dealers. In addition, the hedge ratios and SDRs for the Bellwether bonds are significantly higher than for the two-year notes, which is not surprising given the much longer durations and the equivalency to the cheapest-to-deliver for the Bellwether bond in comparison to the two-year note. Consequently, our analysis of the factors affecting the instability of the hedge ratios is completed for two bond series with significantly different relationships to the futures contract.

TABLES 1A AND 1B ABOUT HERE

Table 2 provides the arithmetic averages, absolute value averages, and standard deviations for the changes of the hedge ratios (HR), CORR, and SDR values for the two bond series. The F-ratios for testing the equality of the variances of the two bond series using the hedge ratios, correlations and SDR variables (the F-ratios are 1.80, 35.73, and 2.22, respectively) shows that these variances are significantly different. The Table 2 results and the associated F-tests support the contention stated above that the two bonds series have different hedge characteristics.[5]

TABLE 2 ABOUT HERE

Tables 1A and 1B show that an instability over time of the hedge ratios and its component factors occurs. Table 2 substantiates the instability of the hedge ratios by determining the average absolute changes in the hedge ratios are .128 and .095, and the standard deviations of the changes are .165 and .123, respectively, for the two bond series.[6] This shows a significant degree of variability in the hedge ratios which, in turn, causes an increase in the risk of a hedged position taken on the basis of the previous quarter's "minimum variance hedge ratio".

B. Distribution Normality

Studentized Range (SR) values for the quarterly results are given in Table 3.[7] All SR values are within the allowable range at the 2 1/2% significance level and all but one value is within the range for a 10% significance level. Hence, the results are consistent with the hypothesis of normality. These results support analysis of the variables by traditional parametric statistics such as linear regression which requires normally distributed variables.

TABLE 3 ABOUT HERE

C. Equality of Variance Tests

Tests for the equality of variances between pairs of ΔHR, ΔCORR, and ΔSDR are found in Table 4. The F-test statistics in column A supports rejection of the hypothesis $\sigma^2(\Delta HR) \leq \sigma^2(\Delta CORR)$; the F-test statistics in column B is consistent with the hypothesis of $\sigma^2(\Delta HR) = \sigma^2(\Delta SDR)$ at the 10% or better significance level. In addition, the F-test statistic in column C support rejection of $\sigma^2(\Delta SDR) \leq \sigma^2(\Delta CORR)$. Thus, the two bonds series have very large F-values for columns A and C in Table 4. These results are consistent with the hypothesis that the volatility in SDR has a greater influence upon HR instability than does the volatility in CORR. As shown in equation (5), the HR is dependent solely upon SDR and CORR. Hence, the instability in HR can be related directly to the greater instability in SDR as compared to CORR.

TABLE 4 ABOUT HERE

D. Rank Correlation Tests

The paired ranks of the changes in HR vs. CORR and HR vs. SDR are examined by Spearman's rank correlation test in order to determine the strength of the associations between these variables. Table 5 shows the Z values for testing ranks (as derived from the D^2 values, where D^2 is the total sum of squares of the differences in each pair of ranks), the correlations between the ranks,[8] and the significance levels. These results clearly show that ΔSDR has a high rank correlation with ΔHR for the Bellwether bond with Z = 6.39 and ρ = .942, while the rank correlation of ΔCORR with ΔHR provides a Z of only

2.12 and a $\rho = .312$ for the Bellwether. The two-year T-note also has a strong relationship between ΔSDR and ΔHR, but ΔCORR and ΔHR ranks and the ρ-value show the importance of the correlation variable for this bond series.

TABLE 5 ABOUT HERE

E. Linear Relationships Between the Variables

To provide a parametric analysis of the relationships between ΔHR, ΔCORR, and ΔSDR, linear regressions between these variables are examined. Initially, the relationship between the two determining factors of the hedge ratio changes, i.e. ΔCORR and ΔSDR, is analyzed. A linear least squares regression model is specified as:

$$\Delta SDR = a_1 + B_1 \, \Delta CORR \qquad (10)$$

The results are given in Table 6. The residual error studentized range (SR) values for (10) are consistent with the hypothesis of normality for the two bond series and the Durbin-Watson statistics are consistent with the hypothesis that no serial correlation exists within the residuals. Thus, these results support the use of traditional parametric tests on B_1.

TABLE 6 ABOUT HERE

The t-test results from Table 6 are consistent with the hypothesis that B_1 equals zero. This is supported by analysis of the low R^2 values of the regression. This suggests that the individual effects of CORR and SDR upon HR instability act independently. This simplifies the analysis of examining the relative effects of these variables on HR changes. In addition, this result supports the validity of the tests of variance equality.

Independence between ΔCORR and ΔSDR occurs because the factors that affect the process generating changes in SDR do not affect changes in CORR, and vice-versa, at least for these bond series. For example, the liquidity and hedging activity involving the Bellwether bond series causes the correlation of the cash and futures prices to be extremely high, while these factors do not significantly affect SDR.

Equation (11) stipulates the linear regression relationship between ΔHR and ΔCORR:

$$\Delta HR = a_2 + B_2 \, \Delta CORR \qquad (11)$$

This model provides a measure of the total variance in ΔHR accounted for by the linear relationships between ΔHR and

ΔCORR. This will be compared to the results from equation (12) which regresses ΔHR on ΔSDR.

The regression and associated results for equation (11) are given in Table 7. The residual error SRs are consistent with the hypothesis of normality. The Durbin Watson values are consistent with the hypothesis of no serial correlation present in the residuals for the Bellwether series.[9] The t-test results on B_2=0 for the Bellwether series is marginally significant at the 1% level and insignificant at the .1% level, while the t-test on the two-year note series is highly significant at the .1% level. Moreover, the regressions only explain 16.4% of the variability in ΔHR for the Bellwether bond series, while explaining 50% of the variability in the two-year note series. The 1/B value provides a value that is easier to interpret in determining the relative importance of the variable in question on ΔHR, since a larger B value means that the independent variable varies less than ΔHR.

TABLE 7 ABOUT HERE

The linear least squares regression of ΔHR on ΔSDR is specified in (12) and the results are given in Table 8:

$$\Delta HR = a_3 + B_3\,\Delta SDR \qquad (12)$$

The t-test results in Table 8 allow for rejection of the hypothesis that B_3 = 0 at the .1% level for Bellwether bond, indicating linear dependence. Moreover, the R^2 and t-values are significantly larger than the corresponding values associated with ΔHR and ΔCORR. The coefficient of determination, R^2, shows that 90.93% of the variance in ΔHR is accounted for by the linear relationship between ΔHR and ΔSDR. The results for the two-year note series show an R^2 of 42.2% between ΔHR and ΔSDR. Although no conclusions can be made concerning causality, these results do indicate that the volatility in SDR is associated with a much greater proportion of HR variance than is the volatility in CORR for the Bellwether series, with both SDR and CORR being important for the two-year note series.

TABLE 8 ABOUT HERE

VI. Relationships to Bond Characteristics

This section relates the characteristics of the two bond series to the results of this paper. A major reason for selecting the two series used here is the differing characteristics of the two bonds. The Bellwether series possesses liquidity and hedging activity which causes it to act similarly to the cheapest-to-deliver cash bond that drives the futures price. In fact, the Bellwether bond has an extremely high and stable correlation with the futures price changes. Alternatively, the two-year note series has a low duration, with differing characteristics from the futures contract, due to its position on the yield curve. Moreover, this series has less liquidity than the Bellwether series.

The Bellwether hedge ratio changes are affected substantially by changes in SDR. Thus, when analyzing the changes in hedge ratios for this important series one need only concentrate on SDR changes. The two-year note hedge ratio changes are affected both by SDR and correlation changes. The results for the Bellwether bond are particularly interesting because this analysis employs intervals of only one week, rather than the typical two to four weeks of other studies. Since shorter intervals typically produce lower correlation values, and hence a greater chance for volatility in the correlations, the dominance of SDR is especially noteworthy.[10]

Specific characteristics that affect the relative SDR volatility of the cash price changes to the futures price changes are the relative maturities, coupons, and interest rate changes of the cash bonds being hedged as compared to the cheapest-to-deliver bond underlying the futures contract. As the Bellwether bond changes, due to the sale of new issues, the coupon changes. The two-year note also changes coupon as the time periods change. In addition, the following factors interrelate with the above characteristics to produce the relevant SDR changes:

- Interest rate changes (shocks) in association with a nonparallel shift in the term structure and/or unequal forward rates will produce changing values of SDR.
- The Conversion Factor Method (CFM) causes biases in the selection of the cheapest-to-deliver instrument, e.g. when yields are greater than 8% then low coupon, long maturity bonds are favored. Thus, when the cheapest-to-deliver bond changes it can have an effect on the volatility of the futures price.[11] Other factors such as the premium bond bias also affects the cheapest-to-deliver bond. (See Trainer (1983) for a discussion of these biases.)
- Timing differences between the last trade for the week for the futures contract versus the last trade for the cash bond create errors in the measured statistical relationship. Liquidity problems (e.g. for the two-year note) also would create timing differences.[12]

The degree of association between the futures and cash price changes, i.e. the correlation, can be related most directly to the degree the asset is associated with the cheapest-to-deliver asset that the futures market follows. In turn, the relationship of the asset in question to the cheapest-to-deliver asset is affected by the liquidity of the cash series and the similarity between the factors affecting the basis between the cash and futures instruments (such as the quality or risk characteristics of the spot instrument and the underlying futures security). For bonds, the behavior of the yield curve in relation to the relative durations of the cash and futures instruments also affects the correlation of the series. Finally, timing differences between the cash and futures price series and the degree of integration of the futures and cash markets will affect the correlation of the series.

The above indicates that additional research is needed to examine the relationship between the bond characteristics and changes in SDR, especially since previous research on futures hedging and cash bond relationships do not provide adequate evidence or models relating to SDR. Such research would further the initial efforts provided here to obtain an explanation and forecast of the future hedge ratio in order to reduce the basis risk when the hedge ratio varies over time.

VII. Conclusions

The importance of unstable hedge ratios to the hedger and the resultant analysis of the underlying factors undertaken in this paper is twofold:

- The use of past data to forecast future hedge ratios and hedging effectiveness must be undertaken with greater care. Previous research implicitly assumes that the hedger possesses ex-post data to determine the hedging effectiveness. Whether a hedge should be employed and the resultant consequences of the proposed hedge position depend on the validity of this assumption. Since unstable hedge ratios increase the basis risk of the hedge in comparison to ex-post results (i.e. the hedging effectiveness is reduced), the hedger may need to reevaluate the firm's analysis procedure for hedging.
- Forecasting future hedge ratios when the hedge ratio is unstable will require information on what factors are causing this variability and an examination of the changes in these factors to determine whether they can be forecasted more precisely than simply using a time series of the hedge ratios or a naive hedge ratio as a substitute for the minimum variance hedge ratio. Analyzing correlation and SDR is the first step in attempting to determine why hedge ratios vary. More precisely, one should relate the characteristics of the individual asset series to correlation and SDR to examine the relationships between the latter factors and the individual characteristics.

The instability in the hedge ratios for the Bellwether bond is associated with changes in the standard deviation ratio. The instability for the two-year bond is associated both with changes in SDR and correlation. These results have important implications for hedgers. First, since an additional risk component exists when hedge ratios are determined from past data, hedgers must determine the effect of this risk on their position. Second, one should determine the factor(s) causing this instability. Further research into the reasons for the instability of SDR and whether this instability exists for other types of futures contracts should be undertaken.

Footnotes

[1] See Daigler (1982,1985,1987, 1988, 1991) for bibliographies on the academic research and practitioner applications of hedging in the interest rate futures markets.

[2] The minimum variance hedge ratio developed by Ederington and employed here and by most other researchers is not optimal under general risk/return preferences, as shown by Figure 1 in Ederington (1979). The minimum risk formulation is employed in most research since it does not require specific information on the hedger's utility function, other than the hedger is a risk minimizer. In addition, the minimum risk situation is more tractable mathematically.

[3] The Bellwether T-bond series is the most recently issued bond series by the Treasury. This series has a significant degree of liquidity due to the large amount of trading by dealers. Moreover, these bonds are hedged in large quantities by the dealers. The Bellwether bond was chosen for its liquidity and near constant maturity. The two-year T-note was chosen since its duration is significantly different from the T-bond futures contract and changes in the yield curve create unstable hedge ratios.

[4] The quarterly periods for the futures expirations end on the last week before the expiration month. Results for the first deferred futures results are almost identical to the nearby results and therefore are not presented here. When the Bellwether bond series changes bonds during the quarter then the bond being removed from the series is sold on the nearest Friday and the new Bellwether bond is purchased on that day. The price changes employed are always between the same bond issue.

[5] All of the tests presented in this paper also were performed using percentage changes of the quarterly results. The results for the Bellwether bond are almost identical to those presented here. The two-year T-not results show marginal non-normality for the correlation variable and less importance overall for the standard deviation ratio. These results are logical given the lower absolute value and thus the large percentage changes of these variables for the two year series.

[6] Since the arithmetic averages of the variables are insignificantly different from zero, no trend in the variables is apparent.

[7] See David, Hartley and Pearson (1954). For applications of SR statistics to financial data see Fama (1976).

[8] The correlation is calculated from $1-[6D^2/N(N^2-1)]$.

[9] The Durbin-Watson values for the two-year series in Table 7 and for both series in Table 8 indicate positive serial correlation of the residuals. These results imply a persistence in volatility as shown by GARCH studies. The large t and R^2 values for these series suggest the significance of these relationships regardless of the marginal serial correlation of the data.

[10] Hegde and Nunn (1985a,b) examine the cross-sectional relationship between various bond characteristics and hedging performance (correlation). They determine that the term to maturity of the spot instrument explains virtually all of the variance in the hedge ratio and hedging performance figures. Hegde (1982) finds that the hedging effectiveness increases from one period to another for a variety of instruments as interest rate volatility increases. In contrast, the current study shows that SDR is more important than correlation in determining the changes in the hedge ratio when a time series analysis is undertaken and the futures and cash have similar characteristics (the Bellwether series).

[11] The Bellwether bond can have a high correlation with the cheapest-to-deliver within any given quarter, while changes in the cheapest from one quarter to the next could cause the SDR to change.

[12] The delivery options associated with the T-bond futures do not enter directly into the futures pricing process since futures prices do not include the delivery month.

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Table 1A: Hedge Ratio Data for the Bellwether T-Bond

Quarter	HR	CORR	SDR	ΔHR	ΔCORR	ΔSDR
Q1 1979	0.821	0.882	0.931			
Q2	0.936	0.891	1.051	0.115	0.008	0.121
Q3	0.894	0.830	1.077	-0.042	-0.060	0.026
Q4	1.122	0.979	1.146	0.227	0.149	0.069
Q1 1980	1.018	0.888	1.146	-0.104	-0.091	0.000
Q2	1.092	0.912	1.198	0.074	0.024	0.052
Q3	1.133	0.947	1.196	0.041	0.035	-0.001
Q4	1.068	0.965	1.106	-0.065	0.018	-0.091
Q1 1981	1.268	0.932	1.362	0.201	-0.034	0.256
Q2	1.247	0.985	1.266	-0.021	0.054	-0.096
Q3	1.510	0.993	1.520	0.262	0.008	0.254
Q4	1.503	0.981	1.533	-0.006	-0.012	0.012
Q1 1982	1.481	0.995	1.489	-0.022	0.014	-0.044
Q2	1.387	0.992	1.399	-0.094	-0.003	-0.090
Q3	1.631	0.996	1.637	0.244	0.005	0.238
Q4	1.195	0.899	1.329	-0.436	-0.097	-0.308
Q1 1983	1.128	0.975	1.157	-0.067	0.076	-0.172
Q2	1.115	0.991	1.125	-0.012	0.017	-0.032
Q3	1.165	0.991	1.175	0.049	-0.001	0.050
Q4	1.111	0.957	1.161	-0.054	-0.034	-0.015
Q1 1984	1.342	0.968	1.386	0.231	0.011	0.226
Q2	1.176	0.966	1.217	-0.166	-0.002	-0.169
Q3	1.181	0.973	1.214	0.004	0.006	-0.003
Q4	1.139	0.924	1.234	-0.041	-0.049	0.020
Q1 1985	1.413	0.988	1.429	0.273	0.065	0.196
Q2	1.270	0.985	1.290	-0.143	-0.004	-0.140
Q3	1.165	0.983	1.185	-0.105	-0.001	-0.104
Q4	1.189	0.965	1.231	0.023	-0.018	0.046
Q1 1986	1.206	0.977	1.235	0.017	0.011	0.003
Q2	0.987	0.962	1.025	-0.219	-0.014	-0.209
Q3	0.711	0.871	0.817	-0.276	-0.092	-0.209
Q4	0.812	0.977	0.831	0.101	0.106	0.014
Q1 1987	1.026	0.944	1.088	0.215	-0.033	0.257
Q2	0.933	0.974	0.959	-0.093	0.030	-0.129
Q3	1.060	0.959	1.105	0.127	-0.014	0.146
Q4	1.190	0.993	1.199	0.130	0.034	0.093
Q1 1988	0.981	0.994	0.987	-0.209	0.001	-0.211
Q2	1.148	0.986	1.165	0.167	-0.008	0.178
Q3	1.288	0.987	1.306	0.140	0.001	0.140
Q4	1.036	0.979	1.059	-0.252	-0.008	-0.247
Q1 1989	1.055	0.997	1.059	0.019	0.018	0.000
Q2	1.148	0.989	1.161	0.093	-0.007	0.102
Q3	1.303	0.980	1.330	0.155	-0.009	0.169
Q4	0.912	0.982	0.928	-0.392	0.002	-0.401
Q1 1990	1.083	0.991	1.093	0.172	0.009	0.165
Q2	1.038	0.990	1.049	-0.046	-0.001	-0.045
Q3	1.112	0.993	1.120	0.075	0.004	0.071

Q4	1.126	0.940	1.197	0.014	-0.053	0.078

Table 1B Hedge Ratio Data for the Two-year T-note

Quarter	HR	CORR	SDR	ΔHR	ΔCORR	ΔSDR
Q1 1979	0.304	0.704	0.433			
Q2	0.384	0.631	0.608	0.079	-0.073	0.176
Q3	0.317	0.762	0.416	-0.067	0.131	-0.193
Q4	0.390	0.770	0.506	0.073	0.008	0.091
Q1 1980	0.111	0.243	0.455	-0.279	-0.527	-0.051
Q2	0.338	0.785	0.431	0.228	0.542	-0.024
Q3	0.234	0.630	0.372	-0.104	-0.155	-0.059
Q4	0.391	0.886	0.441	0.156	0.256	0.069
Q1 1981	0.426	0.872	0.488	0.035	-0.014	0.047
Q2	0.398	0.648	0.613	-0.028	-0.224	0.125
Q3	0.276	0.628	0.440	-0.122	-0.020	-0.174
Q4	0.227	0.530	0.428	-0.049	-0.098	-0.011
Q1 1982	0.488	0.848	0.575	0.261	0.318	0.147
Q2	0.191	0.578	0.331	-0.297	-0.271	-0.245
Q3	0.460	0.938	0.491	0.270	0.360	0.160
Q4	0.290	0.765	0.379	-0.170	-0.173	-0.112
Q1 1983	0.246	0.760	0.323	-0.045	-0.005	-0.056
Q2	0.256	0.868	0.295	0.010	0.108	-0.028
Q3	0.271	0.820	0.331	0.015	-0.048	0.036
Q4	0.173	0.843	0.205	-0.098	0.023	-0.125
Q1 1984	0.357	0.925	0.386	0.184	0.082	0.181
Q2	0.263	0.820	0.320	-0.095	-0.104	-0.066
Q3	0.275	0.916	0.301	0.013	0.096	-0.019
Q4	0.235	0.884	0.265	-0.041	-0.032	-0.035
Q1 1985	0.311	0.892	0.349	0.077	0.008	0.083
Q2	0.271	0.805	0.337	-0.040	-0.087	-0.012
Q3	0.325	0.951	0.342	0.054	0.147	0.005
Q4	0.163	0.583	0.280	-0.162	-0.368	-0.062
Q1 1986	0.145	0.762	0.191	-0.018	0.179	-0.089
Q2	0.179	0.892	0.201	0.034	0.130	0.011
Q3	0.057	0.181	0.313	-0.123	-0.711	0.112
Q4	0.098	0.775	0.126	0.041	0.595	-0.187
Q1 1987	0.087	0.471	0.185	-0.011	-0.304	0.059
Q2	0.168	0.943	0.178	0.080	0.472	-0.008
Q3	0.183	0.920	0.199	0.016	-0.023	0.021
Q4	0.267	0.968	0.276	0.084	0.047	0.077
Q1 1988	0.120	0.900	0.134	-0.147	-0.068	-0.142
Q2	0.069	0.525	0.132	-0.051	-0.374	-0.002
Q3	0.171	0.915	0.187	0.102	0.390	0.056
Q4	0.244	0.891	0.274	0.073	-0.024	0.087
Q1 1989	0.165	0.861	0.192	-0.079	-0.030	-0.082
Q2	0.161	0.420	0.382	-0.005	-0.441	0.190
Q3	0.338	0.892	0.379	0.177	0.472	-0.003
Q4	0.302	0.866	0.348	-0.036	-0.026	-0.031
Q1 1990	0.131	0.727	0.181	-0.170	-0.139	-0.168
Q2	0.198	0.922	0.215	0.066	0.195	0.034

Q3	0.135	0.714	0.189	-0.063	-0.208	-0.026
Q4	0.114	0.662	0.173	-0.020	-0.051	-0.016

Table 2: Summary Statistics on Changes

Series	Arithmetic Average	|Average|	Sample σ
Bellwether:			
HR	0.006	0.128	0.165
CORR	0.001	0.029	0.045
SDR	0.006	0.121	0.155
T-note:			
HR	-0.004	0.095	0.123
CORR	-0.001	0.195	0.269
SDR	-0.006	0.081	0.104

Table 3: Studentized Range (SR) Test

Bond Sample	ΔHR	ΔCORR	ΔSDR
Bellwether:	4.295	5.525*	4.231
T-note:	4.595	4.853	4.194

* normal at the 2 1/2% significance level
All non-starred cells normal at the 10% significance level

Table 4: Tests for Equality of Variances

	A	B	C
Series:	$\sigma^2(\Delta HR)$ vs $\sigma^2(\Delta CORR)$	$\sigma^2(\Delta HR)$ vs $\sigma^2(\Delta SDR)$	$\sigma^2(\Delta SDR)$ vs $\sigma^2(\Delta CORR)$
Bellwether:	13.773 ***	1.130 *	12.192 ***
T-note:	4.758 ***	1.413 **	6.722 ***

* consistent with variance equality at α = 25%
** consistent with variance equality at α = 10%
*** variances significantly different at α = 0.1%

F-ratios calculated as the larger variance divided by the smaller variance.

Table 5: Rank Correlation Tests for ΔHR vs.:				
	Z		ρ-value	
Series:	ΔCORR	ΔSDR	ΔCORR	ΔSDR
Bellwether:	2.118	6.392 *	0.312	0.942
T-note:	4.937 *	4.672 *	0.728	0.689

The unstarred z value accepts the null hypothesis of no rank correlation at the 1% level.
* rejects the null hypothesis of no rank correlation at the 0.2% level.

Table 6: Tests of Association Between ΔCORR and ΔSDR		
Test	Bellwether	T-note
Residual Error Studentized Range	4.350	4.180
Durbin-Watson D Value	2.594	2.963
B_1	0.400	-0.009
$t = B_1/\sigma_{B1}$	0.774 **	0.165 *
R^2	0.013	0.001

* not significant at the 5% level.
** not significant at the 25% level.

Table 7: Tests of Association Between ΔHR and ΔCORR		
Test	Bellwether	T-note
Residual Error Studentized Range	4.358	4.210
Durbin-Watson D Value	2.631	3.183
B_2	1.501	0.324
$1/B_2$	0.666	3.086
$t = B_2/\sigma_{B2}$	2.968 *	6.690 **
R^2	0.164	0.500

* not significant at the .1% level, significant at the 1% level, two-tailed test.
** significant at the .1% level, two-tailed test

Table 8: Tests of Association Between ΔHR and ΔSDR		
Test	Bellwether	T-note
Residual Error Studentized Range	5.647	5.179
Durbin-Watson D Value	3.059	3.196
B_3	1.013	0.772
$1/B_3$	0.987	1.295
$t = B_3/\sigma_{B3}$	21.152 **	5.728 **
R^2	0.909	0.422

* not significant at the .1% level, significant at the 1% level, two-tailed test.
** significant at the .1% level, two-tailed test