Are Multiple Hedging Instruments Better than One?

The case of fixed-rate mortgage-backed securities.

Gregory Koutmos and Andreas Pericli

GREGORY KOUTMOS is professor of finance at Fairfield University's School of Business in Fairfield (CT 06470).

ANDREAS PERICLI is a principal economist at the Federal Home Loan Corporation in McLean (VA 22102).

Following the demise of the GNMA collateralized depository receipt (CDR) in 1987 and the mortgage-backed futures contract (MBF) in 1992, investors and dealers in mortgage-backed securities (MBS) have routinely used cross-hedging instruments to manage risk. Cross-hedging is appropriate when the asset to be hedged differs from the asset that is specified in the futures contract.

The most widely used cross-hedging instrument is the ten-year Treasury note futures contract, even though the duration of the typical thirty-year fixed-rate MBS is lower than the duration of the ten-year Treasury note. The reason for the popularity of the ten-year T-note futures appears to be the high correlation between price changes of the thirty-year MBS and the ten-year T-note. Other cross-hedging instruments, such as the five-year T-note and the two-year T-note futures, are also used, quite often in conjunction with the ten-year T-note futures.

The use of multiple hedging instruments is intuitively appealing, and it has been advocated in the literature. For example, Anderson and Dauthine [1981] advocate the use of multiple hedging instruments to deal with basis risk in cross-hedging situations.

While there are many studies dealing with MBS risk hedging, there has been no empirical investigation into the potential benefit of using multiple hedging instruments, despite the fact that MBS traders routinely use more than one instrument.[1] The assumption appears to be that multiple hedging instruments can be effective in instances of non-parallel yield curve shifts. To facilitate matters, investment banks report hedge ratios using two-year, five-year, and ten-year T-note futures.

Research into the effectiveness of multiple instruments in other areas has produced mixed results. Miller [1985], for example, finds support for the use of multiple instruments in the commodities market. Grant and Eaker [1989] find evidence to the contrary.

Hedging of MBS is extremely complicated, the number of hedging instruments notwithstanding. The difficulty is directly related to the homeowner's prepayment option, which renders the duration and, as a result, the price sensitivity of MBS to changes in interest rates highly uncertain. A better appreciation of this type of uncertainty can be gained by realizing that investing in an MBS is equivalent to taking a long position in a fully amortizing riskless loan and a short position in a call option that gives the mortgagor the right to pay part or all of the outstanding balance at any time.

The two components of the MBS react differently to changes in interest rates. When interest rates rise above the MBS coupon rate, the prepayment option becomes out of the money, and the price of the MBS is a strictly convex function with respect to further increases in interest rates. When interest rates fall, however, the prepayment option becomes in the money, which prevents the value of the MBS from rising, a phenomenon that has been called "negative convexity."

From a methodological point of view, MBS risk hedging has been commonly based on 1) effective duration, and 2) empirical or regression methods. Effective duration is the duration of the MBS adjusted to reflect the duration of the prepayment option, and it measures the price sensitivity of the MBS due to an infinitesimal shift in the yield curve. Effective duration is matched to the duration of a Treasury bond, and the optimal hedge ratio is calculated as the ratio of the two durations.

Estimates of effective duration are extremely sensitive to assumptions concerning prepayment rates and movements in the yield curve. Breeden [1994] finds that effective duration forecasts reported by major investment firms are rather inefficient in the sense that they do not account properly for past information. Specifically, forecasts can be improved considerably by simply incorporating information from past empirical durations. This is an important issue because prepayment overpredicting (underpredicting) will lead to duration underpredicting (overpredicting) and, consequently, to erroneous hedging decisions.

Goodman and Ho [1997] compare the hedging effectiveness of option-adjusted effective duration-based hedge ratios to empirical hedge ratios, and find that empirical hedge ratios perform better. To deal with problems related to non-parallel shifts in the yield curve, Ho [1992] introduces a measure of interest rate exposure called "key rate durations." This approach provides durations with respect to several key rates given any particular pricing model. The advantage is that price sensitivities to different parts of the yield curve can be identified and properly hedged.

Empirical hedge ratios require neither prepayment modeling nor yield curve forecasts. They are usually based on the regression:

$$R_{s,t} = \alpha + \beta R_{F,t} + \varepsilon_t \qquad (1)$$

where $R_{s,t}$ and $R_{F,t}$ are the first logarithmic differences of the spot and the futures prices, respectively; α and β are fixed intercept and slope coefficients, respectively; and ε_t is the random error term, assumed to be an iid process. The minimum-variance hedge ratio is the estimated β that defines the amount of dollars to go short in futures per dollar of investment in the spot (cash) market. The simplicity of the regression approach is undoubtedly one of the reasons for its wide acceptance and use by academic researchers and practitioners alike.[2]

We use empirical methods to investigate for the first time (to our knowledge) the hedging effectiveness of different T-note futures contracts as well as combinations of futures contracts. MBS with various coupons are assumed to be the assets to be hedged; the hedging instruments are two-year, five-year, and ten-year T-note futures contracts.

As expected, the ten-year T-note futures provides the highest reduction in variance when the objective is to use the best single hedging instrument. Moreover, this result holds both within-sample and out-of-sample. When the objective is to use the most effective combination of futures, using all three instruments provides the best results within-sample.

In out-of-sample simulations, however, the three-instrument combination performs worse than simply using the ten-year futures alone. These findings are important, as they suggest that the use of multiple instruments provides inferior hedging results in realistic out-of-sample settings.

HEDGING WITH MULTIPLE INSTRUMENTS

The random return on a hedged portfolio of MBS with short positions of $\beta_1, \beta_2, ..., \beta_n$ dollars worth of futures type 1, 2, ..., n, respectively, for every dollar worth of MBS held is equal to

$$R_{h,t} = R_{s,t} - \beta_1 R_{F1,t} - \beta_2 R_{F2,t} - ... - \beta_n R_{Fn,t} \quad (2)$$

where $R_{h,t}$ is the hedged return; $R_{s,t}$ is the return on the spot asset; β_i is the hedge ratio that corresponds to the futures contract i; and $R_{Fi,t}$ is the return on the i-th futures contract.

The variance of the hedged portfolio is given by:

$$\sigma_h^2 = \sigma_s^2 + \Sigma_i \beta_i^2 \sigma_{Fi}^2 - 2\Sigma_i \beta_i \sigma_{s,Fi} + 2\Sigma_i \Sigma_j \beta_i \beta_j \sigma_{Fi,Fj} \quad \text{for i, j} = 1, 2, ..., n \quad (3)$$

where σ_h^2 is the variance of the hedged returns; σ_s^2 is the variance of the unhedged returns (spot asset); β_i^2 is the hedge ratio for futures contract i; σ_{Fi}^2 is the variance of the returns of the futures contract i; $\sigma_{s,Fi}$ is the covariance of the returns of the spot asset with futures i; and $\sigma_{Fi,Fj}$ is the covariance between the returns of futures i and futures j.

Minimizing the variance of the hedged returns is equivalent to minimizing the variance of the residuals of the multiple regression:

$$R_{s,t} = \beta_1 R_{F1,t} + \beta_2 R_{F2,t} + ... + \beta_n R_{Fn,t} + u_t \quad (4)$$

where $u_t = R_{h,t}$, and the intercept has been suppressed.

The use of multiple hedging instruments is similar in spirit to the use of "key rate durations," since both approaches attempt to measure exposure to particular segments of the yield curve. Estimates of the hedge ratios can be obtained by estimating Equation (4) using the ordinary least squares method (OLS). By its very nature, OLS minimizes the variance of u_t, which is essentially the hedged return. It is assumed that the preconditions for use of the OLS method hold.

DATA AND EMPIRICAL FINDINGS

Data

The data used in this study include daily closing spot prices for the thirty-year fixed-rate GOLD securities issued by the Federal Home Loan Mortgage Corporation (FHLMC) with coupons 7.0%, 7.5%, 8.0%, 8.5%, 9.0%, and 9.5%.[3] The price series have been compiled by the FHLMC. Data used for the futures market are the daily settle prices for the ten-year, five-year, and two-year Treasury note futures contracts (obtained from Tick Data, Inc.).

The delivery months for Treasury note futures contracts are March, June, September, and December. On any given trading day, there are prices for all four outstanding contracts. A time series of non-overlapping observations is created by using the most actively traded contract, thus avoiding problems related to thin trading.

The sample extends from January 4, 1993, through December 16, 1996, for a total of 992 daily

EXHIBIT 1
DESCRIPTIVE STATISTICS

Coupon	$\mu(10^3)$	σ^2	$\rho_{s,F1}$	$\rho_{s,F2}$	$\rho_{s,F3}$
7.0%	0.5318	0.1189	0.9048	0.8887	0.8016
7.5%	−0.4245	0.0901	0.8864	0.8706	0.7904
8.0%	−1.1101	0.0633	0.8422	0.8283	0.7568
8.5%	−1.4379	0.0425	0.7921	0.7866	0.7178
9.0%	−0.3728	0.0263	0.7450	0.7322	0.6878
9.5%	0.6475	0.0199	0.6659	0.6542	0.6120

Pairwise correlations of futures (F_1 = 10-year, F_2 = 5-year, and F_3 = 2-year futures):

$\rho_{F1,F2} = 0.9356$ $\quad \rho_{F1,F3} = 0.8416$ $\quad \rho_{F1,F3} = 0.8597$

Note: Sample period 1/4/1993-12/16/1996; 992 observations. μ and σ^2 are the sample means and variances; $\rho_{i,j}$ are the correlation coefficients between assets i and j. Daily continuously compounded returns calculated as: $\text{Return}_t = \text{Log}(\text{Price}_t/\text{Price}_{t-1})$

prices for each series. The out-of-sample simulations use a holdout sample that extends from October 19, 1995, through December 16, 1996, for a total of 200 observations.

Empirical Findings

Exhibit 1 reports several descriptive statistics on the returns of the MBS and their correlations with the T-note futures contracts. There is a monotonic inverse relationship between coupon size and variance. This is perfectly normal, given that high-coupon (premium) MBS have a lower duration and thus less price sensitivity to changes in interest rates. Across all coupons, the correlation between spot and futures is highest with the ten-year T-note futures. This provides preliminary evidence that hedging with a single instrument is best done with the ten-year futures.

Interestingly, although not unexpectedly, the correlation between the futures returns is very high. Specifically, between the ten-year and the five-year the correlation is 0.93; between the ten-year and the two-year the correlation is 0.84; and, finally, between the five-year and the two-year the correlation is 0.86. Such high correlations indicate that the multiple regression may suffer from multicollinearity.

Exhibit 2 reports the hedge ratios using the hedging instruments one at a time for the entire sample. Judging from the t-statistics, the hedge ratio β is statistically significant at the 1% level in all instances. The estimated Durbin-Watson statistics are always close to 2.0, suggesting

EXHIBIT 2
HEDGING MBS WITH A SINGLE INSTRUMENT

Coupon	β	(t-stat)	σ^2 (hedged)	e (%)	DW
PANEL A. TEN-YEAR T-NOTE FUTURES					
7.0%	0.7787	(66.76)	0.0216	81.85	2.1106
7.5%	0.6639	(60.18)	0.0193	78.56	2.0959
8.0%	0.5289	(49.08)	0.0184	70.91	2.0300
8.5%	0.4074	(40.77)	0.0158	62.71	1.9751
9.0%	0.3018	(35.09)	0.0117	55.46	1.9563
9.5%	0.2344	(28.04)	0.0111	44.23	2.0543
Average	0.4858			65.62	
PANEL B. FIVE-YEAR T-NOTE FUTURES					
7.0%	1.0923	(60.91)	0.0250	78.97	2.0689
7.5%	0.9317	(55.58)	0.0218	75.76	2.0674
8.0%	0.7433	(46.44)	0.0199	68.57	2.0001
8.5%	0.5738	(39.24)	0.0166	60.90	1.9515
9.0%	0.4238	(33.78)	0.0122	53.57	1.9640
9.5%	0.3291	(27.17)	0.0114	42.74	2.0707
Average	0.6823			63.42	
PANEL C. TWO-YEAR T-NOTE FUTURES					
7.0%	2.1363	(42.13)	0.0425	64.42	2.0147
7.5%	1.8332	(40.54)	0.0338	62.44	2.0212
8.0%	1.4717	(36.37)	0.0271	57.24	2.0031
8.5%	1.1432	(32.39)	0.0206	51.48	1.9682
9.0%	0.8626	(29.77)	0.0139	47.25	1.9219
9.5%	0.6671	(24.31)	0.0124	37.39	2.0685
Average	1.3524			53.37	

Note: β and t-stat are the estimated hedge ratios and the associated t-statistics; σ^2 is the variance of the residual of the regression; e is the measure of hedging effectiveness [see Equation (5)]; and DW is the Durbin-Watson statistic testing for first-order serial correlation.

that first-order autocorrelation is not a problem. The size of the minimum hedge ratio varies depending on 1) coupon rate, and 2) the particular hedging instrument used. The amount of the coupon and the size of the hedge ratio are inversely related. This holds true whichever futures contract is used. The explanation of this relationship lies in the fact that high-coupon (premium) MBS have lower duration and thus exhibit lower variability. This in turn leads to lower correlation with the T-note futures and consequently to lower optimal hedge ratios.

Note that the optimal hedge ratio increases as the maturity (and duration) of the asset underlying the futures decreases. Averaging across coupons, the minimum-variance hedge ratio is 0.48 for the ten-year futures, 0.68 for the five-year futures, and 1.35 for the two-year futures.

An important measure is the effectiveness of the cross-hedge. Ederington [1979] suggests using the percentage reduction in variance as a measure of effectiveness:

$$e = 1 - (\sigma_h^2/\sigma_s^2) \tag{5}$$

where σ_h^2 is the variance of the hedged position, and σ_s^2 is the variance of the unhedged position. This measure is essentially the coefficient of determination, or R^2 unadjusted for degrees of freedom.

By this measure, the ten-year T-note futures provides the most effective hedging. Moreover, this holds true across all seven coupons under examination. Next comes the five-year futures and last the two-year futures.

It is apparent that none of the three hedging instruments is particularly effective in hedging the price

EXHIBIT 3
HEDGING MBS WITH MULTIPLE INSTRUMENTS

PANEL A. TEN-YEAR AND FIVE-YEAR T-NOTE FUTURES

Coupon	β_1	(t-stat)	β_2	(t-stat)	σ^2 (hedged)	e (%)	DW
7.0%	0.5062	(15.95)	0.4162	(9.18)	0.0199	83.26	2.0086
7.5%	0.4326	(14.29)	0.3534	(8.17)	0.0181	79.90	2.0110
8.0%	0.3391	(11.36)	0.2899	(6.79)	0.0176	72.18	1.9604
8.5%	0.2548	(9.15)	0.2331	(5.85)	0.0153	63.93	1.9225
9.0%	0.1948	(8.08)	0.1633	(4.74)	0.0115	56.41	1.9276
9.5%	0.1523	(6.47)	0.1254	(3.73)	0.0109	45.02	2.0407
Average	0.3133		0.2635			66.78	

PANEL B. TEN-YEAR AND TWO-YEAR T-NOTE FUTURES

Coupon	β_1	(t-stat)	β_2	(t-stat)	σ^2 (hedged)	e (%)	DW
7.0%	0.6789	(31.91)	0.3670	(5.57)	0.0209	82.39	2.1186
7.5%	0.5681	(28.24)	0.3529	(5.67)	0.0187	79.21	2.0968
8.0%	0.4420	(22.46)	0.3198	(5.24)	0.0179	71.67	2.0263
8.5%	0.3315	(18.28)	0.2793	(4.93)	0.0155	63.57	1.9712
9.0%	0.2307	(14.69)	0.2613	(5.37)	0.0114	56.68	1.9384
9.5%	0.1821	(11.85)	0.1926	(4.05)	0.0109	45.15	2.0558
Average	0.4055		0.2954			66.44	

PANEL C. TEN-YEAR, FIVE-YEAR, AND TWO-YEAR T-NOTE FUTURES

Coupon	β_1	(t-stat)	β_2	(t-stat)	β_3	(t-stat)	σ^2 (hedged)	e (%)	DW
7.0%	0.4900	(15.14)	0.3713	(7.60)	0.1675	(2.42)	0.0198	83.35	2.0157
7.5%	0.4142	(13.44)	0.3024	(6.49)	0.1904	(2.89)	0.0179	80.52	2.0155
8.0%	0.3207	(10.55)	0.2386	(5.19)	0.1916	(2.94)	0.0175	72.40	1.9640
8.5%	0.2375	(0.38)	0.1848	(4.32)	0.1800	(2.97)	0.0152	64.21	1.9254
9.0%	0.1753	(7.17)	0.1090	(2.95)	0.2027	(3.87)	0.0113	57.02	1.9184
9.5%	0.1382	(5.76)	0.8063	(2.38)	0.1463	(2.85)	0.0108	45.41	2.0434
Average	0.2959		0.3354		0.1797			67.15	

EXHIBIT 4
WITHIN-SAMPLE HEDGING EFFECTIVENESS

Portfolio		7.0%	7.5%	8.0%	8.5%	9.0%	9.5%	Average
1. Using 10-yr Futures	σ^2	0.0216	0.0193	0.0184	0.0158	0.0117	0.0111	
	e	81.85%	78.56%	70.91%	62.71%	55.46%	44.23%	65.62%
2. Using 5-yr Futures	σ^2	0.0250	0.0218	0.0199	0.0166	0.0122	0.0114	
	e	78.97%	75.76%	68.57%	60.90%	53.57%	42.74%	63.42%
3. Using 2-yr Futures	σ^2	0.0425	0.0338	0.0271	0.0206	0.0139	0.0124	
	e	64.42%	62.44%	57.24%	51.48%	47.25%	37.39%	53.37%
4. Using 10-yr, 5-yr,	σ^2	0.0198	0.0179	0.0175	0.0152	0.0113	0.0108	
and 2-yr Futures	e	83.35%	80.52%	72.40%	64.21%	57.02%	45.41%	67.15%
5. Using 10-yr and	σ^2	0.0199	0.0181	0.0176	0.0153	0.0115	0.0109	
5-yr Futures	e	83.26%	79.90%	72.18%	63.93%	56.41%	45.02%	66.78%
6. Using 10-yr and	σ^2	0.0209	0.0187	0.0179	0.0155	0.0114	0.0109	
2-yr Futures	e	82.39%	79.21%	71.67%	63.57%	56.68%	45.15%	66.44%
Unhedged Portfolio Variance		0.1189	0.0901	0.0633	0.0425	0.0263	0.0199	

Note: σ^2 is the variance of hedged returns, and e is hedging effectiveness.

risk of premium MBS. The reason is that high prepayments for these coupons induce price compression, the so-called negative convexity. Under these circumstances, the relationship between the hedging instrument and the spot asset breaks down.

Exhibit 3 reports the results for combinations of hedging instruments. The hedge ratios are in all instances significant at the 5% level and in most instances at the 1% level. It appears that, at least within-sample, using multiple instruments is better than using a single instrument. The measure of hedging effectiveness is highest when all three instruments are used. This result holds across all coupons.

Exhibit 4 summarizes the findings on hedging effectiveness within-sample. On the basis of the measure of hedging effectiveness, the empirical evidence suggests that:

1. If a single instrument is to be used, it should be the ten-year T-note futures, as it provides the highest reduction in variance. This holds true whether the MBS to be hedged is a premium or a discount MBS.
2. The use of multiple instruments provides additional risk reduction. Consequently, if transaction costs and contract size are not a problem, all three contracts should be used. Using the 7% coupon as an example, the best single instrument reduces risk by 81.85%, while using all three instruments reduces risk by 83.35%. Similar additional risk reductions can be achieved for the other coupons.

Using within-sample effectiveness measures, however, is not the safest way to evaluate the usefulness of hedging models and related instruments. Out-of-sample evaluation is an alternative and perhaps a more meaningful way of judging the validity and usefulness of a hedging model. Out-of-sample simulations are performed by using the first 792 observations to estimate all models. The holdout sample consists of 200 observations.

At each time period the hedge ratios are calculated, and the models are reestimated by adding one more observation. This process is repeated until the holdout sample is depleted. It should be pointed out that the hedge ratios generated in this manner change over time, as opposed to within-sample hedge ratios, which are static.

The results of the out-of-sample simulations are reported in Exhibit 5. Focusing on the single instrument case, the earlier conclusions hold out-of-sample. Specifically, the ten-year T-note is the best single hedging instrument because it provides the highest reduction in variance. This holds true for all coupons.

The superiority of multiple-instrument hedging vanishes in realistic out-of-sample simulations. The pattern is consistent across all six coupons. Using multiple instruments results in poorer performance than using the ten-year futures only. This result is rather unexpected, because simple intuition suggests that using more instruments could do no harm, given that the additional instruments produce additional variance reduction within-sample.

EXHIBIT 5
OUT-OF-SAMPLE HEDGING EFFECTIVENESS

Portfolio		7.0%	7.5%	8.0%	8.5%	9.0%	9.5%	Average
1. Using 10-yr Futures	σ^2	0.6667	0.6103	0.5978	0.6101	0.5096	0.8745	
	e	94.37%	93.01%	89.53%	82.11%	74.79%	48.32%	80.35%
2. Using 5-yr Futures	σ^2	0.8136	0.7365	0.6986	0.6929	0.5501	0.9089	
	e	93.13%	91.56%	87.76%	79.69%	72.78%	46.28%	78.53%
3. Using 2-yr Futures	σ^2	1.1432	1.1731	0.9526	0.7871	0.5749	0.9575	
	e	90.34%	86.56%	83.31%	76.99%	71.56%	43.41%	75.96%
4. Using 10-yr, 5-yr,	σ^2	0.6943	0.6430	0.6345	0.6578	0.5329	0.9113	
and 2-yr Futures	e	94.13%	92.63%	88.88%	80.72%	73.64%	46.14%	79.35%
5. Using 10-yr and	σ^2	0.6820	0.6292	0.6213	0.6446	0.5269	0.8928	
5-yr Futures	e	94.24%	92.79%	89.12%	81.10%	73.93%	47.23%	79.74%
6. Using 10-yr and	σ^2	0.6776	0.6256	0.6157	0.6337	0.5207	0.9033	
2-yr futures	e	94.27%	92.83%	89.21%	81.42%	74.24%	46.61%	79.76%
Unhedged Portfolio Variance		11.1800	8.7300	5.7100	3.3400	2.2000	1.6900	

Note: σ^2 is the variance of hedged returns, and e is hedging effectiveness. All variances are multiplied by 100. Out-of-sample simulations use a holdout sample that extends from October 19, 1995, through December 16, 1996, for a total of 200 observations.

The source of the problem appears to be the high correlation among the instruments. For example, it can be seen from Exhibit 1 that pairwise correlations are 0.93 (between the ten-year and the five-year), 0.84 (between the ten-year and the two-year), and 0.85 (between the five-year and the two-year).

A rule of thumb for the seriousness of multicollinearity is to compare the pairwise correlations to the coefficient of determination in the relevant regressions. If the former are higher, the problem is serious. In more than 50% of the cases, this holds true.

The implication is that point estimates have higher standard errors. Since these point estimates are the hedge ratios, it should come as no surprise that the use of multiple instruments provides inferior hedging. It is possible that multiple hedging can produce superior results when the instruments are not highly correlated.

SUMMARY AND CONCLUSION

Our research investigates the hedging effectiveness of different T-note futures contracts as well as combinations of futures contracts. Mortgage-backed securities with various coupons are the assets to be hedged; the hedging instruments are two-year, five-year, and ten-year T-note futures contracts.

The ten-year T-note futures provides the highest reduction in variance when the objective is to use the best single hedging instrument. This result holds both within-sample and out-of-sample. When the objective is to use the most effective combination of futures, using all three instruments provides the best results within-sample. In out-of-sample simulations, however, the three-instrument combination performs worse than simply using the ten-year futures alone.

The reason seems to be the high degree of correlation among the instruments, which renders hedge ratios rather inaccurate. These findings are important, as they suggest that the use of multiple highly correlated instruments provides inferior hedging results in realistic out-of-sample settings.

ENDNOTES

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[1]A partial list of studies dealing with MBS risk hedging includes Batlin [1987], Breeden [1991], Ederington [1979], Goodman and Ho [1997], Koutmos, Kroner, and Pericli [1998], and Park and Bera [1987].

[2]It can easily be shown that if futures prices follow a martingale process, then β is also the expected utility-maximizing hedge ratio for an agent with quadratic utility function. See, e.g., Anderson and Dauthine [1981], Ederington [1979], Johnson [1960], and Malliaris and Urrutia [1991], among others.

[3]For more information on GOLD MBS, see Fabozzi [1996, p. 235].

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