The Risk Management Effectiveness of Multivariate Hedging Models in the U.S. Soy Complex

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Several authors have proposed sophisticated multivariate hedging strategies which use portfolio theory and complex econometric techniques. Practical application of these techniques requires using historical data to make decisions about future hedging portfolios. This paper tests to see if there is enough stationarity in the data for these models to actually provide better hedging strategies in practice. For the soy complex the results are clear. No statistically significant improvement over naive equal and opposite hedges was found for any of the multivariate hedging models. So far, there is no known evidence that any of these methods perform reliably in practice. © 2000 John Wiley & Sons, Inc. Jrl Fut Mark 20:189–204, 2000

INTRODUCTION

Because few firms have just one commodity position to be hedged, several authors have questioned the practical relevance of the contributions by Working, Telser, Johnson, Stien, Rolfo, and others, because these models only consider strategies for managing the risk of a single commodity en-

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dowment with a single futures contract.[1] In reality, most firms have multiple endowments of commodities with related prices. As a result, a variety of theoretical models have been proposed that view commodity price risk management as a multivariate portfolio problem. The primary contributors to the theory of multivariate hedging include the original contribution to this area by Anderson and Danthine (1980, 1981), as well as the more recent contributions by Peterson and Leuthold (1987), Tzang and Leuthold (1990), and Fackler and McNew (1993).

The multivariate approach to risk management is logically appealing for firms that have multiple commodity endowments with related prices. Whereas many firms are in this situation to some degree, an especially good example of a firm with multivariate hedging potential is the soybean crusher who purchases soybeans and sells soy meal and soy oil in well-developed markets with correlated prices. In this risk-management setting, all the major inputs and outputs of the firm also have traded futures contracts. In such a case, a univariate risk management focus may actually do damage. If the prices of the inputs and outputs of such firms are positively correlated, the profits of the firm are to some degree "self hedged," and hedging one commodity in isolation may actually increase the overall risk in the firm's profits. Therefore, if the objective is protecting the overall financial performance of a multi-product firm, it is logically appealing to consider the relevant portfolio effects, that is, the extent to which price movements of the firm's endowments are "self hedged," as well as correlations among potential payoffs from futures contracts.

Whereas these models are logically appealing, it is simply not known if they actually will work in practice. The actual effectiveness of these methods has not been tested in a realistic risk-management setting. At present, there are several alternative methods presented in the literature that address the same problem and have identical objectives, but provide different recommendations. As the literature currently stands, a manager wishing to "hedge the crush" in the soy complex has five choices for a hedging strategy. The multivariate hedging models available include the Anderson and Danthine method, the Tzang and Leuthold method,[2] and the Fackler and McNew method. Risk managers might also chose to ig-

[1]These works may still have relevance in the setting where they were intended to apply.
[2]Fackler and McNew quote personal correspondence with Leuthold where he states that he suspects that the Tzang and Leuthold model contains errors. I am including the model in the test because, when I omitted it from a previous version of this article, I drew a strong rebuke from a reviewer. The reviewer was correct. Whereas their hedge recommendations appear implausible (especially for soy oil), it is not known if they would be effective in practice without a test. In addition, I replicated their derivation and found no errors of any kind in the equations. If an error exists, it must be an error in parameter estimation. Therefore, the Tzang and Leuthold model is not included as a "straw man," but because it is not obvious a priori, that it is flawed in any way.

nore covariances, and apply the univariate hedge ratio suggested by Ederington (1979) and others to their multiple commodity positions, or simply choose a equal and opposite hedge for all endowments. Not only is the hedging effectiveness of the various multivariate methods unknown, but it is also not known how the multivariate models compare to these simpler methods. This further emphasizes the need for testing.

Grant and Eaker (1989) did a very thorough and careful job of testing a group of complex hedging strategies. Most importantly, they tested all the models with out-of-sample data. Actual application of any statistical hedging model to a real-world risk management setting requires analysis of historic data to formulate a model, then using the results of the model to make subsequent hedging decisions. There is no escaping this requirement. Using the same data to both estimate a hedging model and test its effectiveness does not measure the model's potential for actual risk management. Grant and Eaker concluded that the complex hedges that they evaluated worked no better than naive or simple hedges. However, the Tzang and Leuthold and the Fackler and McNew methods have appeared subsequent to Grant and Eaker's work. In addition, Grant and Eaker did not test the multivariate Anderson and Danthine model in the way it would be applied to the soy complex where a portfolio of futures contracts is used to hedge a portfolio of endowments. This presents the opportunity to test the risk-management effectiveness of these models with out-of-sample data, compare them to each other, and to simpler methods.

Many questions about the potential use of these methods for risk management in a realistic multivariate setting remain unanswered. Which of the competing approaches to multivariate hedging provides the most risk reduction in an actual risk-management setting? How does the actual risk reduction provided by the multivariate models compare with multiple application of univariate hedging rules or the equal and opposite hedge? How durable are the econometric results of these models in practice? Can a manager use the hedging recommendations provided by these models for years without reestimation, or does the effectiveness deteriorate quickly as estimates of parameters age? Are the recommendations of some of these models more perishable than others? Because the papers by Tzang and Leuthold, and Fackler and McNew both make specific recommendations for risk management in the soy complex, this article also uses data from the soy complex to evaluate these recommendations.

REVIEW OF MULTIVARIATE HEDGING METHODS

Anderson and Danthine made the first contributions to multivariate hedging theory with their 1980 and 1981 articles. Their 1980 article addressed the problem of hedging the aggregate value of a portfolio of spot commodities positions with a portfolio of futures contracts. Their 1981 article applied these multivariate concepts to the problem of cross-hedging. Fackler and McNew also used Anderson and Danthine's theory, but provided a clearer notation, so Fackler and McNew's notation is used here. Suppose an agent has an endowment of m spot (cash) commodity positions. Let **Q** be the vector of these quantities where positive elements represent long cash positions and negative elements are short cash positions (obligations to purchase). In this two-period model, the vector of next period's random cash prices for these commodities is denoted **P**. There are n futures contracts available, and **Z** is the vector of futures positions to be chosen by the decision maker, with positive numbers reflecting long futures positions and negative numbers reflecting short futures positions. The vector of next period's futures prices **F** is also assumed to be a random vector. Denoting the vector of today's prices for future delivery as f, they assume unbiased futures markets, or f = E(**F**). Given these assumptions, the mean and variance of next period's prices may be written:

$$\begin{bmatrix} P \\ F \end{bmatrix} \sim \left(\begin{bmatrix} E(P) \\ f \end{bmatrix}, \begin{bmatrix} \Sigma_{pp} & \Sigma_{pf} \\ \Sigma_{fp} & \Sigma_{ff} \end{bmatrix} \right) \tag{1}$$

where the Σ_{pp} is the variance-covariance matrix for spot prices, Σ_{ff} is the variance-covariance matrix for futures prices and Σ_{fp} is the covariance matrix between cash and futures prices. Where C(**Q**) is the cost function, the firm's random profit is:

$$\pi = P'Q - C(Q) + (F - f)'Z. \tag{2}$$

The first-order condition for the variance-minimizing futures position **Z** in terms of the known cash position **Q** is:

$$Z = -\Sigma_{ff}^{-1}\Sigma_{fp}Q. \tag{3}$$

This shows the surprising result that the risk-minimizing portfolio of futures contracts needed to hedge the value of a portfolio of spot endowments depends on the variance of the futures prices, and the covariance of the futures with themselves (Σ_{ff}), and the covariances of futures prices with cash prices (Σ_{fp}), but it does not depend on the covariances of the cash endowments with themselves (Σ_{pp}). In other words, the risk-minimizing hedge is not necessarily reduced by the extent that the firm's endowments are "self hedged" by the correlations between the values of its own commitments. Whereas this curious result can be explained, it will not be dealt with here. The method suggested by Anderson and Danthine for estimating **Z** was to estimate all the elements in Σ_{ff} and Σ_{fp} in the usual way, and then calculate the Z vector by inverting Σ_{ff} as shown in eq. (3).

A recent article by Fackler and McNew proposes an alternative technique for estimating the Anderson and Danthine Z vector. Their contribution is a multivariate generalization of a univariate method proposed by Myers and Thompson (1989). They assumed that delivery period spot prices (p_t) and delivery period futures prices (f_t) arise from the following linear model:

$$p_t = X_{t-1}\alpha + u_t \quad f_t = X_{t-1}\beta + v_t$$

where X_{t-1} is a vector of the factors that affect the supply and demand for the commodity.[3] These reduced form equations forecast delivery period spot and futures prices with the information on the that is available in the period when the hedge is placed. Regarding the X as non-stochastic, the variability in p and f arises only from the forecast error terms, u and v. Given this, the risk minimizing hedge ratio estimator is the ratio of the covariance of u and v over the variance of v. This gives a hedge ratio based on a covariance and a variance that are conditional on the information available at the time the hedge is placed rather than the simple unconditional covariance and variance. The Fackler and McNew method is a multivariate generalization of this logic. Based on data from the years 1985 through 1992, Fackler and McNew's model recommended variance-minimizing hedge ratios (absolute value) of 1.171 for soybeans, 1.107 for soy oil, and 1.279 for soy meal. They also showed that their coefficient estimates were stable in the last part of the sample period. Historical stability of these coefficients would give a manager reason to think that they could be usefully employed for risk management in subsequent periods.

Tzang and Leuthold also applied portfolio theory to the problem risk minimization in the setting of soybean crushing. Given the portfolio of spot endowments for the crusher, which includes the input of soybeans, and the outputs of meal and oil produced by the crush, they solved for the risk minimizing portfolio of futures contracts for soybeans, meal and oil. Although they referenced the work by Anderson and Danthine, they did not use their results. Instead, they wrote out the expression for the crusher's returns, found its variance, differentiated this variance w.r.t the

[3] Fackler and McNew used lagged cash and futures prices and monthly dummies.

three futures contracts and solved for the three variables with Cramer's rule. They used data from January 1983 through June 1988, and made variance-minimizing hedging recommendations for different hedging time horizons. The results were relatively insensitive to the length of the horizon and the average recommended hedge ratios (absolute value) were 1.01 for soybeans, 0.21 for soy oil and 0.84 for soy meal.

EMPIRICAL TEST OF MULTIVARIATE HEDGING METHODS IN THE SOY COMPLEX

The overall objective of this empirical testing is to provide information that would be useful for a person who intended to actually apply one of these models to a practical situation. The specific objectives are to:

1. Determine which of the multivariate risk management recommendations provides the most risk reduction when applied in a realistic way to out-of-sample data.
2. Measure the durability of these recommendations—that is, determine how the relative risk reduction changes as the estimated parameters of the hedging model get older and older.
3. Compare the risk reduction provided by the multivariate methods to risk reduction provided by univariate risk-minimizing hedge ratios and naive equal-and-opposite hedges.

These objectives are accomplished by taking the actual hedging recommendations of the Fackler and McNew and the Tzang and Leuthold models and applying them to the data that immediately follows the sample period that they used to estimate their models. This is like taking their recommendations and immediately putting them into practice in the real world. This procedure provides a test of what was actually recommended by Fackler and McNew and Tzang and Leuthold. If I attempted to apply their models to a new data set, it could not be determined if poor risk-management performance arose from the failure of their method, or from my mistake in implementing their method. Using their actual hedge recommendations eliminates this potential confound.[4] The weakness of this design is that the risk management efficiency of the Fackler and McNew model cannot be directly compared to the Tzang and Leuthold model.[5] Instead, the performance of these models in both cases is compared to

[4]Another view of this is represented by Tomek's view on confirmation of results. Although I am very sympathetic with this view, I think one should see if the original form of these models would have actually worked on out-of-sample data before worrying about confirmation in Tomek's sense.
[5]If Leuthold's reported suspicions are correct, this may not be a serious weakness.

the results from the Anderson and Danthine model, the multivariate application of a standard univariate risk-minimizing model,[6] and the simple equal and opposite hedge. Then, these comparisons are continued over 60 months to see how the relative risk-management effectiveness of these methods may change over time.

It should be pointed out that the same basic theoretical solution to the multivariate hedging problem is used by Anderson and Danthine, Fackler and McNew, and Tzang and Leuthold. In all cases their objective is to minimize the variability of the profits of a soybean crusher. Naturally, the mathematical solution is the same in all cases. The Tzang and Leuthold approach appears to be different because they use a more realistic three period model where the hedge on the soybeans is lifted before the hedges on the meal and oil, because of the required time for crushing. If the periods are collapsed to the usual two, the Tzang and Leuthold solution becomes identical to that of Anderson and Danthine.

Because the basic mathematics underlying the solution is the same, the differences arise from the different conventions chosen for data handling, planning horizon, and estimation methods. The basic difference between the estimation methods used by Anderson and Danthine, and Fackler and McNew are discussed above, but in addition to these differences are basic data handling conventions. For example, Fackler and McNew used average monthly prices, whereas Tzang and Leuthold used weekly prices. Fackler and McNew used 12 years of historical data, whereas Tzang and Leuthold used different amounts of historical data depending on the hedging horizon. So, what is being tested is if one of these sets of assumptions about the planning and hedging horizon, data handling methods, and estimation techniques produces a more effective hedging strategy in actual practice.

The first test compares the risk management effectiveness of Tzang and Leuthold's recommendations with the recommendations of the Anderson and Danthine model, univariate risk-minimizing hedges placed on all endowments, and a simple equal and opposite hedge for all endowments. The test period starts with data from July 1988, the first month after the end of the data used by Tzang and Leuthold to generate their recommendations, and continues for 60 subsequent months. The univariate risk-minimizing hedge ratios and the Anderson and Danthine hedges are based on variances and covariances estimated in the usual way from the 376 observations of daily prices (18 months) immediately prior to July 1988.

[6]For example, Ederington (1979).

The second test compares the effectiveness of the Fackler and McNew recommendations to the Anderson and Danthine model, univariate risk-minimizing hedges placed on all endowments, equal and opposite hedge for all endowments. This test period starts in January 1993, the first month after the end of the data used to estimate the parameters for the Fackler and McNew model. Again, these results are also calculated over the following 60 months through the end of 1997.

Because all of the multivariate methods have the objective of minimizing the variance of the hedger's profits, this was the measure used to evaluate the performance of the models. All methods were evaluated by their ability to reduce the day-to-day variance in the market value of the hedged endowment of a soybean crusher. The specific endowment is for a soybean crusher who intends to purchase soybeans and sell soy meal and soy oil at some future time. Because one bushel of soybeans produces approximately 11 pounds of soy oil and 48 pounds of soy meal, the spot endowment is assumed to be a short position of one bushel of soybeans and a long positions of 11 pounds of soy oil and 48 pounds of soy meal. Therefore, where the variable ordering is soybeans, soy oil, soy meal, the endowment vector $\mathbf{e} = [-1, 11, 48]$.

The risk management effectiveness of the various strategies is measured by calculating the daily values of the spot endowment, and adding to this the daily values of the futures position recommended by the various strategies. Then, the variance of the total of the two is calculated for each month, for the 60 months following the date of the model. Let $\mathbf{f}_t$ be an array of realizations of the daily futures prices and $\mathbf{c}_t$ an array of the realizations for the daily spot cash prices ($/unit) for soybeans, soy oil, soy meal, where the subscript t denotes the number of months since the end of the data period used to estimate the hedging model. The array of daily spot values of the endowment $\mathbf{sv}_t$ is calculated by multiplying each column of $\mathbf{c}_t$ by the corresponding element of the endowment vector $\mathbf{e}$, then summing the rows. Similarly, the daily value of the recommended hedge portfolio $\mathbf{hv}_t$ is calculated by multiplying the vector of recommended hedge positions times the realizations of daily futures prices, and summing. The elements in the vector of recommended hedge positions is simply the recommended hedge ratio times the endowment. For example, for the equal and opposite hedge, the recommended hedge ratios are $[+1, -1, -1]$, meaning that you go long in the futures market 100% of the soybean endowment, and short 100% of the endowments of soy oil and soy meal. The recommended hedge positions for the equal and opposite hedge are $\mathbf{h}_s = [+1, -11, -48]$ which means that the futures market position is to go long 1 bushel of soybeans, and short 11 pounds

TABLE I

Recommended Hedge Ratios and Recommended Hedge Positions
From Various Methods

	Recommended Hedge Ratio			*Recommended Hedge positions*		
Method	*soybeans*	*soy oil*	*soy meal*	*soybeans*	*soy oil*	*soy meal*
Equal and Opposite	+1.00	−1.00	−1.00	+1.00	−11.0	−48.00
Tzang & Leuthold	+1.01	−0.21	−0.84	+1.01	−2.31	−40.32
Fackler & McNew	+1.171	−1.107	−1.279	+1.171	−12.177	−61.39
Anderson & Danthine[a]	+1.245	−1.154	−1.280	+1.245	−12.694	−61.420
Anderson & Danthine[b]	+1.312	−1.906	−1.082	+1.312	−20.962	−51.927
Univariate[a]	+0.940	−1.039	−0.945	+0.940	−11.430	−45.370
Univariate[b]	+0.944	−1.047	−1.007	+0.944	−11.518	−48.314

[a]Estimated from the 376 daily observations (18 mo) prior to the beginning of the test period for the Tzang & Leuthold model.
[b]Estimated from last 380 daily observations (18 mo) prior to the beginning of the test period for the Fackler & McNew model.

of soy oil and 48 pounds of soy meal. This is consistent with the assumption that, in the setting of soy bean crushing, the problem of choosing an integer number of contracts does not limit the accuracy of the hedge.

The recommended hedge ratios and corresponding hedge positions from the various methods are compared in Table I. The daily values of the hedged endowment are calculated by summing the elements of $\mathbf{sv}_t$ and $\mathbf{hv}_t$. The standard deviation of this sum is used as the measure of the relative effectiveness of the hedging strategy for the month t. Repeating these calculations over 60 months for each of the hedging strategies gives a measure of the variability of the value of the endowment that would have been realized if the various hedge recommendations had been followed, and how they would have compared over time. These comparisons are made over two time periods.

THE DATA

Futures prices on the nearby contracts for soybeans, soy meal, and soy oil traded on the Chicago board of trade were collected from the Dow Jones news service. Daily settlement prices for the nearby contract were collected for the ten-year period 1988 through 1997. All prices were converted to dollars per bushel for soybeans and to dollars per pound for soy oil and soy meal. The nearby contract was defined as the contract closest to expiration, except during the delivery month. Table II shows which contract was defined as the nearby contract for each commodity for each month. The January contract expires in the subsequent year.

TABLE II

Definition of Nearby Futures Contacts for Soy Products on Chicago Board of Trade

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Soybeans	mar	mar	may	may	jul	jul	aug	sep	nov	nov	jan	jan
Soy meal	mar	mar	may	may	jul	jul	aug	sep	oct	dec	dec	jan
Soy oil	mar	mar	may	may	jul	jul	aug	sep	oct	dec	dec	jan

TABLE III

Tests of Differences in Performance of Multivariate Hedging Models

Multivariate Method	*Test Period*	*Ave Monthly Variance*	*Z(p) values*
Fackler-McNew	Jan 93–Dec 97	89.10	
Anderson-Danthine	Jan 93–Dec 97	120.05	Z = −.069 (0.48)
Anderson-Danthine	Jul 88–Jun 93	57.68	
Tzang-Leuthold	Jul 88–Jun 93	113.48	Z = −1.56(0.12)

The cash prices collected were from the Central Illinois processor prices collected by the Market news service of the USDA. Because they report only the high and a low price observed for each commodity for each day, the midpoint of the high and low price was used as a proxy for the average cash available to a processor on a given day. Processor cash prices were collected for #1 yellow soybeans, 44% protein soy meal, 48% protein soy meal and bulk soy oil. Since the Chicago Board of Trade changed the minimum protein content requirement from 44% to 48% on the soy meal contract, the cash price series includes the 44% protein soy meal in the initial part of the series, and switches to the price of the 48% protein soy meal as of the October 1992 contract.

THE RESULTS

The first objective of the study is to compare the risk-management effectiveness of the three multivariate methods of hedging. Using the Anderson-Danthine method as the numeriare, and using just point estimates of the average variance, Table III shows that the Fackler-McNew method works better than the Anderson-Danthine method during the January 1993–December 1997 test period, and that the Anderson-Danthine method works better than the Tzang-Leuthold method during the July

TABLE IV

Effect of Time on Portfolio Variance

Dependent variable: Variance of hedged endowment.
Independent variable: Months since model estimation.

Model	*Sample Period*	*Slope Estimate*	*Standard Error*	*t statistic*
Anderson-Danthine	Jul 88–Jun 93	−2.15	0.852	−2.52
Tzang-Leuthold	Jul 88–Jun 93	−4.81	1.77	−2.72
Equal and Opposite	NA	−1.81	0.606	−2.99

1988–June 1993 test period. Although it is tempting to assume transitivity and say that the Fackler-McNew method works better than the Tzang-Leuthold method, there is no real basis for making this claim from these results. However, because none of these differences are statistically significant for $\alpha = 0.05$,[7] there is no strong statistical support for claiming any of these models superior to the others. The lack of statistical power is not the result of an excessively small sample either, because all hedges were tested on the basis of five years of daily data.

The second objective of this test is to evaluate the durability of the results of these models. My working hypothesis was that patterns in the covariance structure would change over time and the effectiveness of these models would deteriorate over time as the estimates of the covariance structure became more and more out of date. To test this proposition, I regressed the monthly variances of the hedged endowments on time to see if, on average, the variance was increasing as the estimates became obsolete. Unfortunately, the regression results showed that the variances were decreasing over time, which seemed to suggest that the performance of the models was improving as the parameter estimates were becoming more out-of-date. Table IV shows these regression results. Because this interpretation of the data seemed so completely implausible, I regressed the variances of the portfolios based on the equal and opposite hedge on time to see if the overall ambient riskiness in the soy complex had been declining over this period. This suspicion was confirmed with a t statistic of nearly three. These results are also shown in Table IV.

Therefore, it seemed that a better measure of the deterioration of the benefits from estimating the covariance structure would be to look at the variance of the endowments hedged with the multivariate models

[7]It is tempting to think that an F test should be used, but I am not testing for a difference between two variances. The test is for a difference between two means of monthly variances where the sample size is large. Therefore, a Z statistic was used.

TABLE V

Effect of Time on Relative Performance of Multivariate Hedging Models

Model	*Sample Period*	*Slope Estimate*	*Standard Error*	*t statistic*
Anderson-Danthine	Jul 88–Jun 93	−0.005	0.002	−2.35
Anderson-Danthine	Jan 93–Dec 97	−0.017	0.018	−0.97
Tzang-Leuthold	Jul 88–Jun 93	0.031	0.078	0.40
Fackler-McNew	Jan 93–Dec 97	0.006	0.005	1.32

Dependent variable: Ratio of portfolio variance to variance from qual and opposite hedge.
Independent variable: Months since model estimation.

TABLE VI

Hedging Effectiveness of Tzang-Leuthold and Anderson-Danthine Models

Hedging Strategy	*Average monthly variance of value of hedged endowment*	*Number (%) of months better than the equal and opposite hedge*	*Number (%) of months worse than the equal and opposite hedge*	*z value (p value) for test for difference from the equal and opposite hedge*
Equal and Opposite	48.691	0	0	NA
Risk Minimizing (Ederington)	46.419	32 (53.33%)	28 (46.67%)	z = 0.149 (p = 0.88)
Anderson-Danthine	57.681	20 (33.33%)	40 (66.67%)	z = −0.4585 (p = 0.65)
Tzang-Leuthold	113.48	5 (8.33%)	55 (91.67%)	z = −1.899 (p = 0.057)

Sample period: July 1988–June 1993 (60 months)

relative to the risk realized with a simple equal and opposite hedge. The results from using a dependent variable created by dividing the monthly variances by the variance from the equal and opposite hedge are shown in Table V.

None of the multivariate models showed any statistically significant deterioration of effectiveness (increase in variance) over time. One of the Anderson-Danthine models actually showed a statistically significant improvement in relative performance as the estimates of the covariance structure became increasingly obsolete, but it does not seem reasonable to generalize from this result. Taken as a whole, the tests of deterioration of the multivariate hedging models seem to indicate that their performance does not appear to deteriorate over time in an absolute sense, or relative to a naive method of hedging.

The third objective was to compare the effectiveness of the various multivariate hedging methods with simple models like the risk-minimizing hedge ratio suggested by Ederington and others, and the most simple strategy of all, the equal and opposite hedge. The results of these tests are shown in Tables VI and VII.

Table VI shows the results of the July 1988–June 1993 test period where the Tzang-Leuthold method is compared to the Anderson-Danthine method, the multivariate application of the Ederington method, and the equal and opposite hedge. In this test, the average variance was lowest for the Ederington method at 46.4, slightly higher for the equal and opposite hedge at 48.7, the Anderson-Danthine method was third at 57.7, and the Tzang-Leuthold method was last at 113.5. Statistical tests easily confirmed the null hypothesis that these results were no different than the equal and opposite hedge for the Ederington and Anderson-Danthine methods, but the p value for the Tzang-Leuthold method was nearly at the traditional 5% significance level at 0.057. This creates suspicion that the poor performance of the Tzang-Leuthold model is not due to just sampling error, and Leuthold's suspicion that the model contains errors appears to be consistent with the results. Whereas the statistical evidence is not up to the traditional standard, the Tzang-Leuthold model performed worse than the equal and opposite hedge in 55 out of 60 of the test months. This alone would possibly persuade a practical person to not use the Tzang-Leuthold model for real-world risk management. The very slight differences from the equal and opposite hedge that were realized by the Ederington and Anderson-Danthine methods could not be used to support a claim that they performed either better or worse. It is clear from the very high p values, however, that there is no evidence from this test to suggest that either of these statistically-based hedging methods should be recommended over the simple equal and opposite hedge for real-world risk management.

Table VII reports the results of the second test period where the Fackler-McNew model was compared to the Anderson-Danthine model and the equal an opposite hedge. In this test, the simple equal and opposite hedge had the lowest average variance at 86.2, the multivariate application of the Ederington method was nearly identical at 86.5, the Fackler-McNew method was close third at 89.1 and the Anderson-Danthine method was fourth at 120.5. In no case, however, were there any p values which would even hint that any of these were different than the equal and opposite hedge in a statistically significant way. Because the equal and opposite hedge performed better than any of the statistically based hedging methods in this test, it seems clear that there is no basis for recommending any of these methods for practical risk management, even if it cannot be proven that they are worse. That is, Occam's Razor

TABLE VII

Hedging Effectiveness of Fackler-McNew and Anderson-Danthine Models

Hedging Strategy	*Average monthly variance of value of hedged endowment*	*Number (%) of months better than the equal and opposite hedge*	*Number (%) of months worse than the equal and opposite hedge*	*z value (p value) for test for difference from the equal and opposite hedge*
Equal and Opposite	86.182	0	0	NA
Risk Minimizing (Ederington)	86.53	25 (41.67%)	35 (58.33%)	$z = 0.0086$ ($p = 0.99$)
Anderson-Danthine	120.5	12 (20%)	48 (80%)	$z = -0.773$ ($p = 0.43$)
Fackler-McNew	89.104	28 (46.67%)	32 (53.33%)	$z = -0.069$ ($p = 0.94$)

Sample period: January 93–December 1997 (60 months)

suggests that the equal and opposite hedge should not be contraindicated unless an alternative method can be clearly demonstrated to be better.[8]

CONCLUSIONS AND RECOMMENDATIONS

When the objective is to chose a hedging strategy that minimizes the day to day variability of a "crush" endowment in the U.S. soy complex,[9] the following conclusions appear to be supported by this study. (i) When the effectiveness of the Anderson-Danthine, Fackler-McNew and Tzang-Leuthold multivariate hedging methods are compared, none can be shown to be statistically superior to the others. However, there is reason to suspect that the published results of the Tzang-Leuthold model contain an error. (ii) There is no evidence to suggest that the effectiveness of these models deteriorates over time. This result is not really relevant, however, because: (iii) There is no evidence to suggest that any of the multivariate hedging models or the univariate risk-minimizing model offer any risk-management advantages over a simple equal and opposite hedge.

Where the real world risk manager is concerned about the day-to-day variation in the value of the hedged endowment, these conclusions lead to a clear recommendations for practical risk management in the U.S. soy complex. (i) It does not appear that there is any evidence that

[8]A reviewer pointed out that I missed the multivariate hedging model proposed by Garcia, Roh, and Leuthold (1995). They attempted to improve hedging performance by using a sophisticated MGARCH model. Fortunately, they did test their model on out-of-sample data, and found results consistent with those reported here. Even though they found a very minor improvement over the naive strategy, they did not assert that the difference was statistically significant.

[9]Even this objective may be flawed. Collins shows that observed hedging behavior may arise from a disaster-avoidance objective.

any of the multivariate hedging models will outperform the simple equal and opposite hedge. This is consistent with the previous evaluation of other complex hedging strategies done by Grant and Eaker (1989). (ii) In addition, there is not even any evidence to support using the univariate risk-minimizing model of Ederington over the equal and opposite hedge.

The appropriate recommendations for future research are less obvious. One possibility would be to evaluate other risk management situations to see if a multivariate setting may be found where one of the multivariate hedging models will yield consistently good results in out-of-sample data. Another would be to critically evaluate univariate hedging models to see if an environment can be found where even these models consistently work better than an equal and opposite hedge with out-of-sample test data.

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