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Testing the Performance of Multiproduct Optimal Hedging

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Recent steady growth in the volatility of commodity markets, and the increasing need for proper risk management tools in production settings that make use of inputs and outputs in futures markets, may be addressed via multiproduct hedging. This study determines and contrasts the effectiveness of multiproduct optimal hedging – that incorporate time-varying correlations – between storable and non-storable commodity settings, especially during recent periods of increased volatility. A soybean complex is considered for storable production-related commodities, and a feedlot operator is considered for non-storable production-related commodities.
Multiproduct optimal time-varying hedge ratios are determined via a multivariate state dependent model of regime switching dynamic correlations. This model estimates time-varying correlations for multiple series in different correlation regimes (i.e., the conditional correlations matrix is not constant in this model). Two correlation regimes are estimated for the time periods considered, for both storable and non-storable production settings. More importantly, significant improvement of multiproduct hedging is determined for the storable commodity setting – soybean complex- over simple hedging strategies with time-varying correlations and the naive strategy (1:1 hedge ratio). However, there is no significant improvement found for the non-storable commodity setting – feedlot operator – over simple hedging strategies with time-varying correlations; yet there is improvement over a naive hedging strategy. These latter results are corroborated using two different data sets for cash prices of feeder and live cattle.

Key Words: price volatility, multiproduct hedging, time-varying hedge ratios, storable agricultural commodities, soybean complex, non-storable commodities, feedlot operator.

Introduction

Multiproduct hedging considers a multivariate portfolio approach with the potential advantage of production-related commodities decreasing the price risk faced over the case of singular commodity hedging strategies. The recent surge in volatility of agricultural commodity markets, coupled with an increasing demand for enhanced risk management tools in production settings making use of inputs and outputs in futures markets, may be addressed with multiproduct hedging. These production-related commodities may be storable, as in the case of a soybean complex, or they may be non-storable as in the case of cattle production, such that each context involves different market conditions and risks. This study tests the effectiveness of multiproduct hedging ratios incorporating time-varying correlations, in a storable and non-storable commodities setting especially considering recent periods of increased volatility.

Multiproduct optimal time-varying hedge ratios are determined for storable commodities, and likewise for non-storable commodities, by applying a multivariate state dependent model of regime switching dynamic correlations. The multivariate model is able to estimate simultaneously time-varying correlations for multiple series in two or more different regimes (i.e., the conditional correlations matrix is not constant in this model). The hedging effectiveness of these multiproduct optimal hedge ratios are compared with the simple hedge ratios determined from the commodities in the multiproduct setting. More importantly, the hedging effectiveness of the multiproduct hedge ratios from storable commodities is compared to that of the non-storable commodities. Hence the relationship between storable commodities and a multiproduct hedging setting is tested for optimal hedging performance over that of non-storable commodities in a multiproduct setting.

Several studies have addressed multiproduct hedging in the past. Anderson and Danthine (1980) lay the theoretical ground for a static scenario, where the hedge between multiple contracts in an efficient market responds to the covariance between the future and cash prices and the variance of the future prices. Subsequent studies by Peterson and Leuthold (1987), Tzang and Leuthold (1990), Fackler and McNew (1993), Garcia et al. (1995), Noussinov and Leuthold (1999), Haigh and Holt (2000) and Manfredo et al. (2000) determined empirical estimates of multiproduct optimal hedges with relative advantages over single commodity hedging strategies. Yet a study by Collins (2000) found no significant improvements of multiproduct hedging methods. Most of these latter studies sought to incorporate the condition denoted by Myers and Thompson (1989) and Baillie and Myers (1991), whereby the covariance between cash and future prices considers information up to the date when the hedge is made (i.e., conditional variance/covariance matrix).

The prior condition of an up-to-date variance/covariance matrix imposes difficulties in the estimation process of multiproduct time-varying hedge ratios, as it requires that the conditional correlation matrix be positive semi-definite for each estimated period. Thus some of the previous mentioned studies considered a constant correlation matrix within a changing variance setting (MGARCH models). Manfredo et al. (2000), Haigh and Holt (2002) and recently Tejeda and Goodwin (2010) have estimated multiple hedge ratios in a time-varying covariance/variance matrix, with favorable results for periods of higher volatility in the latter studies.

Only recent studies have compared the optimal hedging performance between storable and non-storable commodities. However to the best of our knowledge, no study up to date considers a multiproduct setting that incorporates these commodity properties. Yang and Awokuse (2003) estimated optimal hedge for five storable and three non-storable commodities, finding improved hedging effectiveness of the storable commodities over the non-storable. More recently, Choudry (2009) and Mann and Septhon (2010) considered time-varying correlations in their studies and both papers determined that there was not a significant difference in the hedging effectiveness between the two types of commodities, although Mann and Sephton (2010) found that the futures markets for livestock performs rather poorly. In any case, as mentioned previously, none of these papers study the difference between commodities within a multiproduct hedging setting.

A framework for the application of the multiproduct hedging method – considering a soybean complex as a storable commodity setting and a feedlot operation as a non-storable commodity setting – is presenteded below. This is followed by the econometric methods applied, including brief model details. A description of the data sets is presented afterwards, followed by parameter and optimal hedging results for both commodity settings, including comparison to simple hedging strategy with time-varying correlations, and naïve (1:1) hedge strategy. Discussions and conclusions follow.

Multiproduct Hedging in a Storable commodity Setting - Soybean Complex

A soybean processor operation requires soybeans as input and results in soybean meal and soybean oil as output. Hence the return or margin from the soybean process is the difference between the sale prices of soybean meal and soybean oil and the cost prices of soybeans. This margin varies according to the variability of these prices, and soybean processors may hedge these three prices in the cash markets, forward cash markets, and the futures and options markets. This study considers hedging only with futures instruments.

The processor's crushing margin depends on the ratio of input/output soybean crushing technology employed. It is assumed here that 48 pounds of soybean meal and 11 pounds of soybean oil are produced from each bushel of soybeans (i.e. 59 lbs.), neglecting any loss for simplicity.

A framework in line with Tzang and Leuthold (1990), Garcia et al. (1995), and Manfredo et al. (2000) for soybean processing, is established considering two stages in a total of three periods or weeks in this case. The first stage involves two weeks in production planning (i.e. previous to the actual purchase of soybeans). Here futures hedges include concurrently going long (i.e. buy) in soybeans[1] ($F_{b,t-3}$) and short (i.e. sell) in both soybean meal ($F_{m,t-3}$) and soybean oil ($F_{o,t-3}$). The second stage involves the operation, which includes one week in actually buying the soybeans in the cash market ($S_{b,t-1}$) and concurrently placing a short ($F_{b,t-1}$) in the futures market, thus liquidating previous soybeans long position. Subsequently, after a week following a period of crushing, the producer sells the soybean meal ($S_{m,t}$) and soybean oil ($S_{o,t}$) in the cash market and concurrently places a long in the futures markets for both these outputs ($F_{m,t}$ and $F_{o,t}$), and thus liquidates previous shorts of soybean meal and soybean oil. Hence the hedged soybean returns or margin, considering the two previous stages (with two periods/weeks for planning and one period/week for operation), is as follows:

$$R_t = S_{m,t} + S_{o,t} - S_{b,t-1} + b_{b,t-3}\,(F_{b,t-1} - F_{b,t-3}) - b_{m,t-3}\,(F_{m,t} - F_{m,t-3}) - b_{o,t-3}\,(F_{o,t} - F_{o,t-3}) - c$$

where b_b, b_m, b_o are respectively soybeans, soybean meal and soybean oil bushels of futures contracts on a per bushel soybean basis at the first time period t-3, and c is a processing cost which is assumed constant. The optimal number of bushels of futures contracts will determine the respective optimal hedge ratio, obtained by minimizing the variation of the returns as mentioned previously.

That is, by using the mean variance framework described in the introduction under the condition of unbiased futures markets, (i.e. expected futures price differences being equal to zero), we are able to determine the minimum hedge ratios from the variance of the returns[2] presented below, as per Garcia et al. (1995) and Manfredo et al. (2000).:

$$V(R) = V(S_b) + V(S_m) + V(S_o) + b_b^2 V(F_b) + b_o^2 V(F_o) + b_m^2 V(F_m) - 2\mathrm{cov}(S_o, S_b) - 2\mathrm{cov}(S_m, S_b) +$$

$$+ 2\mathrm{cov}(S_m, S_o) - 2b_b\mathrm{cov}(F_b, Sb) + 2b_b\mathrm{cov}(F_b, S_o) + 2b_b\mathrm{cov}(F_b, S_m) + 2b_o\mathrm{cov}(F_o, S_b) -$$

[1] Soybean is denoted by subscript "b"; Soybean meal is denoted by subscript "m"; Soybean oil is denoted by subscript "o".

[2] The time scripts are omitted for simplicity.

$- 2b_o cov(F_o, S_o) – 2b_o cov(F_o, S_m) – 2b_o b_b cov(F_o, F_b) + 2b_m cov(F_m, S_b) – 2b_m cov(F_m, S_o) –$

$- 2b_m cov(F_m, S_m) – 2b_m b_b cov(F_m, F_b) + 2b_m b_o cov(F_m, F_o).$

The minimum variance hedge ratios are obtained by partially differentiating the previous variance with respect to b_b, b_m, b_o and equating each to zero, and then solving for each b_b, b_m, b_o, which is calculated with Cramer's rule for simplicity. These time-varying hedge ratios are computed by concurrently estimating the time-varying variances and covariance terms.

Multiproduct Hedging in a Non-Storable commodity setting - Cattle Production

A simple framework of the final 'fattening' sequence of cattle production or of a feedlot operator requires corn, soybean meal and feeder cattle as input to 'fatten' the calf, resulting in fed cattle as output for slaughter. Thus the feedlot margin is the difference between the sale price of slaughter cattle and the purchasing price of corn, soybean meal and feeder cattle. As in the soybean complex, this study only considers hedging with futures instruments, leaving the alternative of hedging with options and forward cash markets for further study.

The feedlot operator's margin is in line with a previous study by Noussinov and Leuthold (1999). Thus it is assumed that 700-pound steers are purchased by the feedlot operator and fed with 42 bushels of corn and 100 pounds of soybean meal during about four months (18 weeks), for an approximate gain of 3.3 pounds a day. This results in a final weight of about 1,100 pounds, before sale for slaughter.

A framework is established considering three stages during a total of 22 periods or weeks. Similar to the soybean complex, the first stage involves production planning but here four weeks of planning are considered (i.e., previous to the actual purchase of inputs). Hence futures hedges include concurrently going long in corn[3] ($F_{c,t-22}$), soybean meal ($F_{m,t-22}$) and feeder cattle ($F_{fc,t-22}$) and going short in fed cattle or live cattle ($F_{lc,t-22}$). The second stage, at the fifth week, begins the operation by actually buying the corn, soybean meal and feeder cattle in the cash market ($S_{c,t-18}$, $S_{m,t-18}$, $S_{fc,t-18}$, respectively) and concurrently placing a short ($F_{c,t-18}$, $F_{m,t-18}$, $F_{fc,t-18}$, respectively) in the futures market for these inputs, thus liquidating these previous long positions. Subsequently, after 18 weeks of a 'fattening' period, the producer sells the fed cattle ($S_{lc,t}$) in the cash market and places a long in the futures markets for this output ($F_{lc,t}$), liquidating its previous position.

Thus the hedged feedlot operator's returns or margin, considering the three previous stages, is:

$$R_t = S_{LC,t} - (S_{C,t-18} + S_{M,t-18} + S_{FC,t-18}) + b_{C,t-22}(F_{C,t-18} – F_{C,t-22}) + b_{M,t-22}(F_{M,t-18} – F_{M,t-22}) + b_{FC,t-22}(F_{FC,t-18} – F_{FC,t-22}) – b_{LC,t-22}(F_{LC,t} – F_{LC,t-22}) - c$$

where, similarly to the soybean complex, b_c, b_{sm}, b_{fc} and b_{lc} are respectively corn, soybean meal, feeder cattle and fed or live cattle futures contracts on a per fed cattle basis (i.e., 1100 pounds) at the first time period t-22, and c is a processing cost which is assumed constant. Once again, the optimal number of 'heads of fed cattle' futures contracts determines the respective optimal hedge ratio, obtained by minimizing the variation of the returns. This latter is noted below:

[3] Corn is denoted by subscript "c", Soybean meal is denoted by subscript "m", Feeder cattle is denoted by subscript "fc" and Fed or Live cattle is denoted by subscript "lc".

$$
\begin{aligned}
V(R) = {} & V(S_c) + V(S_m) + V(S_{fc}) + V(S_{lc}) + b_c^2 V(F_c) + b_m^2 V(F_m) + b_{fc}^2 V(F_{fc}) + b_{lc}^2 V(F_{lc}) + \\
& 2cov(S_c, S_m) + 2cov(S_c, S_{fc}) - 2cov(S_c, S_{lc}) + 2cov(S_m, S_{fc}) - 2cov(S_m, S_{lc}) - 2cov(Sf_c, S_{lc}) \\
& + 2b_c cov(F_c, S_{lc}) - 2b_c cov(F_c, S_c) - 2b_c cov(F_c, S_m) - 2b_c cov(F_c, S_{fc}) \\
& + 2b_m cov(F_m, S_{lc}) - 2b_m cov(F_m, S_c) - 2b_m cov(F_m, S_m) - 2b_m cov(F_m, S_{fc}) \\
& + 2b_{fc} cov(F_{fc}, S_{lc}) - 2b_{fc} cov(F_{fc}, S_c) - 2b_{fc} cov(F_{fc}, S_m) - 2b_{fc} cov(F_{fc}, S_{fc}) \\
& - 2b_{lc} cov(F_{lc}, S_{lc}) + 2b_{lc} cov(F_{lc}, S_c) + 2b_{lc} cov(F_{lc}, S_m) + 2b_{lc} cov(F_{lc}, S_{fc}) \\
& + 2b_c b_{fc} cov(F_c, F_{fc}) + 2b_{fc} b_m cov(F_{fc}, F_m) - 2b_{fc} b_{lc} cov(F_{fc}, F_{lc}) + 2b_c b_m cov(F_c, F_m) \\
& - 2b_c b_{lc} cov(F_c, F_{lc}) - 2b_m b_{lc} cov(F_m, F_{lc})
\end{aligned}
$$

Econometric Methods

The conditional mean and covariance of market prices must be defined in order to estimate the conditional time-varying covariance matrix. For this purpose, the conditional returns of the respective spot and futures prices are identified and computed (i.e. in order for the covariance matrix to be estimated). In line with Manfredo et al. (2000), the soybean cash and futures prices consider the timing between planning and production period, resulting in the following conditional returns:

$R_{b,t} \mid I_{t-3} = 100*ln(P_{b,t-1}/P_{b,\ t-3})$; *P being either Spot or Futures Price.*

or $R_{b,t} = 100*ln(P_{b,t-1}/P_{b,\ t-3}) + u_{b,t}$ (1.1)

with information available at the planning stage, (i.e. at *t-3*), and P being Spot or Futures prices.

Likewise, the following conditional returns are obtained for soybean meal and soybean oil:

$R_{x,t} \mid I_{t-3} = 100*ln(P_{x,t} / P_{x,t-3})$; *P being either Spot or Futures Price.*

or $R_{x,t} = 100*ln(P_{x,t} / P_{x,t-3}) + u_{x,t}$ *x being soybean meal or soybean oil* (1.2)

In analogous form, the conditional returns for corn, soybean meal, feeder cattle and live cattle spot and futures prices are given by:

$R_{y,t} \mid I_{t-22} = 100*ln(P_{y,t-18}/P_{y,\ t-22})$; *P being either Spot or Futures Price.*

or $R_{y,t} = 100*ln(P_{y,t-18}/P_{y,\ t-22}) + u_{y,t}$; *y being corn, soybean meal or feeder cattle* (1.3)

$R_{lc,t} \mid I_{t-22} = 100*ln(P_{lc,t}/P_{lc,\ t-22})$; *P being either Spot or Futures Price.*

or $R_{lc,t} = 100*ln(P_{lc,t}/P_{x,\ t-22}) + u_{lc,t}$; (1.4)

The prediction errors are specified as the time-varying covariance matrix:

$H_t = E(\varepsilon_t \varepsilon_t' \mid I_{t-3})$ *for soybean complex* (1.5)

or $H_t = E(\varepsilon_t \varepsilon_t' \mid I_{t-22})$ *for feedlot operator* (1.6)

Estimation of the time-varying variances and covariances of cash and futures price changes is made with the parsimonious model from the Regime Switching Dynamic Correlation (RSDC) model (Pelletier, 2006 and Tejeda et al., 2009).

The RSDC model considers a K - multivariate time process:

$$Y_t = H_t^{1/2} U_t \quad \text{with } U_t \sim i.i.d.(0, I_K) \tag{1.7}$$

Where Y_t are the previous price returns from (1.1) to (1.4)

The time varying covariance matrix H_t to be estimated is decomposed into standard deviations and correlations, with different correlation values switching between different regimes through a Markov chain.

$$H_t \equiv S_t \Gamma_t S_t \tag{1.8}$$

where S_t is a Diagonal matrix with standard deviations: $s_{k,t}$ $k = 1 \ldots\ldots K$ and Γ_t is the correlations matrix

The standard deviations $s_{k,t}$ for each time series k - from the diagonal matrix S_t, are assumed to follow an ARMACH model, per Taylor (1986). In the ARMACH model, the conditional standard deviation follows:

$$s_t = \omega + \sum_{i=1}^{q} \tilde{\alpha}_i |y_{t-i}| + \sum_{j=1}^{p} \beta_j s_{t-j} \quad \text{with } \tilde{\alpha}_i = \alpha_i / E|\tilde{u}_t|\text{, for stationary purposes} \tag{1.9}$$

The correlation matrix Γ_t in the parsimonious or restricted model is:

$$\Gamma_t = \Gamma \lambda(\Delta_t) + I_K\big(1 - \lambda(\Delta_t)\big) \tag{1.10}$$

where Γ is a fixed KxK correlation matrix – for every state or regime considered. I_K is a KxK identity matrix. And $\lambda(\Delta_t) \in [0,1]$[4] is a univariate random process governed by the unobserved Markov chain process Δ_t that takes 2 possible values ($\Delta_t = 1,2$) and is independent of U_t. Hence, the correlation matrix at time t (i.e. Γ_t) is a weighted average of two extreme regimes – uncorrelated returns at $\lambda(\Delta_t) = 0$, or highly correlated returns at $\lambda(\Delta_t) = 1$. Changes among correlations of different regimes are strictly proportional to $\lambda(\Delta_t)$. The 'probability law' governing the Markov chain process Δ_t is defined by its state dependent transition probability matrix Π_t with elements of row i and column j : $\pi_t^{i,j}$, which is a function of a weakly exogenous variable x_{t-1}. For this study the x_{t-1} variable is omitted by setting equal to zero (i.e., resulting in constant transition probabilities), leaving for a future study the introduction of fundamental factors in the state dependent transition probabilities and gauging their effect.

Data – Soybean Complex

Weekly spot and futures prices for soybeans, soybean meal and soybean oil are taken for each Wednesday of the week, and if missing, then the value for that week's Tuesday or Thursday is considered. The cash soybean prices are quotes from the Central Illinois elevator and the soybean meal and soybean oil prices are quotes from Decatur, Illinois. The futures quotes are for

[4]for assurance of eliminating possibilities of non-PSD correlation matrix

the closing prices at the Chicago Board of Trade (CBOT). Prices from futures contracts consider the nearest maturity contract, excluding from the particular maturity month. All data is obtained from the Commodity Research Bureau (CRB) data set and spans from the second week of January in 2001 until the first week of October 2008, consisting of 408 observations. The out of sample data consists of weekly prices from the second week of October 2008 till the last week of April 2009, being 27 observations.

Data – Feedlot Operator

Two separate data sets were used in estimating the optimal feedlot operation multiproduct hedges, arriving both at similar results. The first set considers weekly spot and futures prices for corn, soybean meal, feeder cattle and live cattle for each Wednesday. Similar to the soybean complex, if a value is missing it is replaced by either Tuesday or Thursday's value. The cash prices for feeder cattle are from Oklahoma City, and for fed cattle are the average from Texas-Oklahoma, both cash prices obtained from the CRB database. The futures prices for feeder cattle and live cattle are from Chicago Mercantile Exchange (CME), likewise obtained from the CRB data. Once again, prices from futures contracts consider the nearest maturity contract, excluding from the particular maturity month. Corn and Soybean meal cash and future prices are obtained similarly to the soybean complex. This set of data spans from December 1998 to the first week in October 2008, for 513 observations. The out of sample data was from October 2008 to December 2009, for 64 observations.

The second data set differs from the previous by considering weekly spot and futures prices for each Monday in the case of corn, soybean, and feeder cattle. Cash and futures data for corn and soybean meal are obtained from the CRB. The futures data for feeder cattle is likewise from CRB. However, the cash prices for feeder cattle are from the Oklahoma City Stockyards, obtained directly from the USDA. In addition, the cash prices for slaughter or live cattle are for the spot weighted average price from Texas and Oklahoma, for a 35%-65% choice steer at 1100-1150 pounds, for each Friday of the week. In case there was no Friday price, a Thursday or Wednesday was picked. The futures prices for live cattle are similarly for Fridays. These two different days selected for the spot prices of feeder and cattle prices were taken upon considering the regular local trading day of the week. This data set is from the second week of August 2001 to the end of August 2010, with 448 observations. The out of sample data is from the end of August to the first week of November 2010, for only 10 observations.

Results - Soybean Complex

Tables 1 and 2 present estimated correlation values between the cash and future prices of soybean, soybean meal and soybean oil for the two regimes considered. The chart in figure 1 shows the dynamic correlation between the two regimes for soybean cash prices and soybean futures.

Regarding the different correlation regimes, it may be noted that each specific commodity has two significant dynamic correlation regimes between their cash and futures prices. Thus soybeans, soybean meal and soybean oil each have two significantly different correlation levels between their spot and futures prices. These different correlation levels are quite similar for the three commodities, ranging from almost one at 0.99 for regime 1 to about 0.94 at regime 2. The correlation values between soybean spot prices and soybean meal futures prices ranges from 0.745 for regime 1 to 0.704 for regime 2; and the correlation values between soybean meal and

soybean oil spot prices ranges from 0.458 for regime 1 and 0.432 for regime 2. However, in both these latter instances, the magnitude of the value of the difference between the regimes appears small when compared to the magnitude of their standard errors. Hence, there may not be a significant difference between regimes for these latter comparisons.
The ARMACH model results for each price are in table 3. In general, the ARMACH parameters are significant for all price series, except those of soybean oil. For this latter case, the conditional volatility is only significantly dependent upon the previous observation or innovation, and not upon the previous volatility.

The average hedge ratios are computed considering each regime and compared to a simpler hedge ratio which only considers the time-varying covariance between spot and futures returns[5], without taking into account the existing relationship between the different soybean products. These settings are compared to the case of naive hedging, which is equivalent to the hedge ratio being equal to 1 (i.e. agents take equal but opposite positions in the futures contracts to the corresponding cash position). Results are presented in table 4. As may be noted, the difference in average hedge ratios between the two regimes is larger when the model takes into account the multiple dynamic relationships between soybean, soybean meal and soybean oil than for the case of a simple hedge consisting of a single product.

The following tables 5 and 6 contain the hedging effectiveness[6] provided by the two methods estimated. This is the hedging effectiveness considering the two regimes from the multivariate RSDC model compared to the univariate cash futures covariance/variance quotient – where the two estimated regimes may also be taken into account but in a univariate form. Both these cases are compared to the naive hedging method (i.e. hedge ratio equal to 1), and to the case of the soybean complex not being hedged at all. Table 5 contains the average, variance and the hedging effectiveness for hedge ratios from the in sample data, and Table 6 contains the same statistics for the out of sample data. In both cases, there is an improved hedging effectiveness by using the regime switching model of dynamic correlations.

Results show that for the soybean complex (i.e., storable commodities), there is an improvement of variance reduction by using a combination of the regimes from the model with Time Varying Correlations. Thus it is better in comparison to the simple hedging method that may combine or not the two estimated regimes, and likewise better than the naïve hedging method. Improvements of over 3 percentage points are obtained in comparison of this former model to the naive model for in sample data, yet only a bit more than half a percentage point for out of sample data. Perhaps more data may be required in this latter case to obtain an improved variance reduction of the hedge ratio.

Results – Feedlot Operation

For the first data set, the estimated correlation values between the cash and future prices of corn, soybean meal, feeder cattle and live cattle for the two regimes considered are in tables 7 and 8, respectively. The estimated results for the second data set are quite similar to these. Moreover,

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[5] Consistent with traditional optimal hedge ratios, $b_{i,t-3} = \frac{Cov(S_i, F_i)}{Var\,(F_i)}$ per Manfredo et al. (2000)

[6] Percentage reduction in the variance of the hedged margin with respect to the unhedged margin, equal to $1 - \frac{Var(hedged)}{Var(unhedged)}$, per Manfredo et al. (2000).

the optimal hedging results are the same as obtained with the first data set. Therefore only these first are presented, yet the other results are available upon request. The chart in figure 2 shows the dynamic correlation between the two regimes for soybean meal spot prices and soybean meal futures prices.
Corn and soybean meal have two significant different regimes between their spot and futures prices. These correlation regimes fluctuated between 0.98 and 0.80, with a larger range than in the previous soybean complex. In the case of feeder cattle and live cattle prices, the magnitude of their standard errors may result in the two correlation regimes between their spot and future prices being significant at a higher than 10% level for the type I error. The correlation values between the two regimes for corn futures and soybean meal cash or live cattle cash range from 0.58 to 0.47 and -0.054 and -0.04, respectively, with these latter two being non-significant.

The ARMACH model results for each price are in table 9. In general, all the conditional volatility parameters are only significantly dependent upon the previous observation or innovation and not dependent on the previous conditional volatility. Only in the case of cash prices of corn and live cattle is the previous conditional volatility parameter also significant.

Table 10 contains the average hedge ratios obtained for the in-sample and out-of-sample data. Similarly to the soybean complex, the hedge ratios that take into account the multiple correlations among the commodities estimated by the multivariate model result in a larger range between the two regimes. Moreover, the average hedge ratios for feeder cattle are much smaller at 0.4 and 0.2 than a full naive hedge, and smaller than the simple hedge, at both the in-and-out of sample data.

Results for the hedging effectiveness of the feedlot operation are in table 11. These indicate that despite an improvement of the model over the naive hedge, by a larger reduction of margin variance, this is not the case in comparison to the simple hedge. That is, there is not an improvement of the multiproduct hedging strategy over the simple strategy that takes into account the time-varying correlation. This result is corroborated by estimated parameters from the second data set mentioned previously, which takes into account feeder cattle spot prices directly from the source (i.e., from Oklahoma City Stockyard receipts) and from live cattle spot prices from the USDA.

Discussions & Conclusions

Multiproduct time-varying optimal hedge ratios are determined and contrasted for two different settings, using a multivariate state dependent model of regime switching dynamic correlations. The settings consisted of storable commodities - a soybean crushing process, and non-storable commodities – a feedlot operation. The model applied depicted the time-varying correlations for multiple series of cash and future prices in two different regimes.

Results indicate hedging improvement by applying the multivariate model for the storable commodity setting, in comparison to simple time-varying hedges and a naïve hedging method. This is the case of a soybean complex, where multiproduct optimal hedge ratios produced the lowest variability of the resulting margin. Moreover, the optimal hedge ratios obtained were lower than the simple hedge and much lower than a full hedge.

Regarding the non-storable commodity setting that considered a cattle production operation, there was not an improvement obtained by the multiproduct hedging strategy. The multiproduct hedge ratio was better than the naive hedge at reducing margin variance, but it did not offer improvement over the simple time-varying hedge ratio. Perhaps this may be due to a non-significant difference between the correlations at each regime of spot and future prices for both feeder cattle and live cattle prices, and was corroborated by the estimated results using the second data set. In other words, the model is not able to capture much difference for spot and future prices of either feeder cattle or live cattle among these two correlation regimes, such that it makes an impact in the optimal multiproduct hedge. It is important to mention that a relevant assumption that may have an effect on this resulting strategy is that we do not allow for hedging adjustment. That is, we assume that each week once the hedge strategy is set, it is not adjustable at a subsequent week. This factor may have a role in the previous result given the long number of weeks the hedge operation requires to complete. A future study may incorporate relaxing this assumption, among others.

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Table 1. Regime 1 - Correlation Values for Soybean Complex

Regime 1	*Soybean Cash*	*Soybean Meal Cash*	*Soybean Oil Cash*	*Soybean Futures*	*Soybean Meal Futures*	*Soybean Oil Futures*
Soybean Cash	1.0000					
	-					
Soybean Meal Cash	0.7273	1.0000				
	0.0314	-				
Soybean Oil Cash	0.5858	0.4575	1.0000			
	0.0324	0.0431	-			
Soybean Futures	0.9911	0.7130	0.5864	1.0000		
	0.0023	0.0330	0.0329	-		
Soybean Meal Futures	0.7449	0.9865	0.4810	0.7366	1.0000	
	0.0301	0.0034	0.0417	0.0309	-	
Soybean Oil Futures	0.5982	0.4636	0.9948	0.5992	0.4906	1.0000
	0.0332	0.0439	0.0013	0.0338	0.0419	-

Table 2. Regime 2 - Correlation Values for Soybean Complex

Regime 2	*Soybean Cash*	*Soybean Meal Cash*	*Soybean Oil Cash*	*Soybean Futures*	*Soybean Meal Futures*	*Soybean Oil Futures*
Soybean Cash	1.0000					
	-					
Soybean Meal Cash	0.6874	1.0000				
	0.0303	-				
Soybean Oil Cash	0.5537	0.4325	1.0000			
	0.0310	0.0409	-			
Soybean Futures	**0.9367**	0.6739	0.5542	1.0000		
	0.0086	0.0318	0.0315	-		
Soybean Meal Futures	0.7041	**0.9324**	0.4547	0.6962	1.0000	
	0.0291	0.0088	0.0396	0.0299	-	
Soybean Oil Futures	0.5654	0.4382	**0.9402**	0.5664	0.4637	1.0000
	0.0317	0.0417	0.0084	0.0324	0.0398	-

Table 3. Armach values – Soybean Complex

	Soybean		*Soybean Meal*		*Soybean Oil*	
	Cash	*Futures*	*Cash*	*Futures*	*Cash*	*Futures*
ω - omega	0.8197*	0.9763+	1.6248*	1.3673+	4.2507*	4.5348*
	0.3762	0.5012	0.7736	0.7240	1.0303	0.9748
α~ - alpha tilda	0.1828*	0.1688*	0.1677*	0.1274*	0.2649*	0.2702*
	0.0323	0.0364	0.0389	0.0286	0.0403	0.0451
β - beta	0.7012*	0.6804*	0.6563*	0.7128*	0.0608	0.0048
	0.0993	0.1292	0.1251	0.1196	0.1974	0.1835

*Significance at 5% level or less +Significance at 10% level or less

Table 4. Average Hedge Ratios – Soybean Complex

Average Hedge Ratio - RSDC Model _ **In Sample**

	Soybean	*Soybean Meal*	*Soybean Oil*
Regime 1	1.0733	1.1580	0.9912
Regime 2	0.4183	0.7561	0.7475

Average Hedge Ratio - Simple Hedge - **In Sample**

	Soybean	*Soybean Meal*	*Soybean Oil*
Regime 1	1.0173	1.1173	0.9985
Regime 2	0.8808	0.9661	0.8924

Average Hedge Ratio - RSDC Model **- Out of Sample**

	Soybean	*Soybean Meal*	*Soybean Oil*
Regime 1	1.1407	1.1691	1.0293
Regime 2	0.4827	0.7499	0.7335

Average Hedge Ratio - Simple Hedge **- Out of Sample**

	Soybean	*Soybean Meal*	*Soybean Oil*
Regime 1	1.0848	1.1260	1.0367
Regime 2	0.9387	0.9744	0.8971

Table 5. **Hedging Effectiveness – Soybean Complex**

Hedging Effectiveness - In Sample

Model		Mean	Variance	Percent Reduction
Unhedged		1.2665	0.1541	
Naive		1.2477	0.0641	*58.4024*
Simple	Regime 1	1.2433	0.0762	50.5129
	Regime 2	1.2436	0.0731	52.5328
	Combined	1.2426	0.0675	*56.2110*
RSDC	Regime 1	1.2469	0.0712	53.7724
	Regime 2	1.2396	0.1092	29.1071
	Combined	1.2293	0.0596	*61.3272*

Table 6. **Hedging Effectiveness – Soybean Complex**

Hedging Effectiveness - Out of Sample

Model		Mean	Variance	Percent Reduction
Unhedged		1.3459	0.1859	
Naive		1.2688	0.0125	*93.27*
Simple	Regime 1	1.2700	0.0182	90.24
	Regime 2	1.2742	0.0156	91.63
	Combined	1.2729	0.0154	*91.73*
RSDC	Regime 1	1.2686	0.0172	90.74
	Regime 2	1.2876	0.0234	87.42
	Combined	1.2826	0.0112	*94.00*

Table 7 Regime 1 - Correlation Values for Feedlot Operation

Regime 1	*Corn Cash*	*Soybean Meal Cash*	*Feeder Cattle Cash*	*Live Cattle Cash*	*Corn Futures*	*Soybean Meal Futures*	*Feeder Cattle Futures*	*Live Cattle Futures*
Corn Cash	1.0000 -							
Soybean Meal Cash	0.5779 0.0377	1.0000 -						
Feeder Cattle Cash	-0.1249 0.0455	0.0172 0.0464	1.0000 -					
Live Cattle Cash	-0.0333 0.0636	0.0606 0.0693	0.1304 0.0598	1.0000 -				
Corn Futures	**0.9416** 0.0097	0.5704 0.0367	-0.1307 0.0456	-0.0336 0.0622	1.0000 -			
Soybean Meal Futures	0.5827 0.0359	**0.9839** 0.0018	-0.0457 0.0476	0.0661 0.0696	0.5813 0.0356	1.0000 -		
Feeder Cattle Futures	-0.2074 0.0444	-0.0963 0.0466	0.3900 0.0415	0.0227 0.0701	-0.1705 0.0454	-0.1046 0.0462	1.0000 -	
Live Cattle Futures	-0.0435 0.0497	-0.0427 0.0526	0.0948 0.0502	0.7115 0.0706	-0.0540 0.0504	-0.0498 0.0527	0.0074 0.0543	1.0000 -

Table 8. Regime 2 - Correlation Values for Feedlot Operation

Regime 2	*Corn Cash*	*Soybean Meal Cash*	*Feeder Cattle Cash*	*Live Cattle Cash*	*Corn Futures*	*Soybean Meal Futures*	*Feeder Cattle Futures*	*Live Cattle Futures*
Corn Cash	1.0000							
	-							
Soybean Meal Cash	0.4680	1.0000						
	0.0358	-						
Feeder Cattle Cash	-0.1011	0.0139	1.0000					
	0.0371	0.0376	-					
Live Cattle Cash	-0.0270	0.0490	0.1056	1.0000				
	0.0515	0.0562	0.0486	-				
				-				
Corn Futures	**0.7626**	0.4619	-0.1059	0.0272	1.0000			
	0.0316	0.0350	0.0372	0.0504	-			
Soybean Meal Futures	0.4719	**0.7968**	-0.0370	0.0536	0.4708	1.0000		
	0.0347	0.0320	0.0385	0.0564	0.0345	-		
					-			
Feeder Cattle Futures	-0.1679	-0.0780	0.3158	0.0183	0.1381	-0.0847	1.0000	
	0.0365	0.0378	0.0359	0.0568	0.0372	0.0376	-	
					-			
Live Cattle Futures	-0.0352	-0.0346	0.0768	0.5762	0.0437	-0.0404	0.0060	1.0000
	0.0403	0.0427	0.0408	0.0617	0.0409	0.0427	0.0440	-

Table 9 Armach values – Feedlot Operation

	Corn		*Soybean Meal*		*Feeder Cattle*		*Live Cattle*	
	Cash	*Futures*	*Cash*	*Futures*	*Cash*	*Futures*	*Cash*	*Futures*
ω - omega	0.3124*	0.4277*	0.4885*	0.4903*	0.2461*	0.1968*	3.6883*	4.5753*
	0.0952	0.0728	0.1217	0.1133	0.1205	0.0291	0.6608	0.8846
α~ - alpha tilda	0.2672*	0.2709*	0.3882*	0.3512*	0.4208*	0.5199*	0.7280*	0.4991*
	0.0472	0.0333	0.0374	0.0347	0.0804	0.0724	0.1439	0.0499
β - beta	0.3334*	0.1463	0.0167	0.0111	0.1405	0.0023	0.1400*	0.0247
	0.1679	0.1196	0.1793	0.1707	0.3063	0.1005	0.0576	0.1008

* Significant at the 5% level or less

Table 10 Average Hedge Ratios for Feedlot Operation

Average Hedge Ratio - RSDC Model - **In Sample**

	Corn	*Soybean Meal*	*Feeder Cattle*	*Live Cattle*
Regime 1	1.0078	1.1637	0.3930	0.9437
Regime 2	0.8910	0.9874	0.2565	0.7631

Average Hedge Ratio - Simple Hedge - **In Sample**

	Corn	*Soybean Meal*	*Feeder Cattle*	*Live Cattle*
Regime 1	1.1579	1.0318	0.4987	0.9456
Regime 2	0.9382	0.8355	0.4057	0.7672

Average Hedge Ratio - RSDC Model - **Out of Sample**

	Corn	*Soybean Meal*	*Feeder Cattle*	*Live Cattle*
Regime 1	1.0216	1.1746	0.3027	0.7866
Regime 2	0.9170	0.9925	0.1816	0.6370

Average Hedge Ratio - Simple Hedge - **Out of Sample**

	Corn	*Soybean Meal*	*Feeder Cattle*	*Live Cattle*
Regime 1	1.1517	1.0617	0.4048	0.8002
Regime 2	0.9326	0.8598	0.3278	0.6409

Figure 11 Hedging Effectiveness – Feedlot Operation

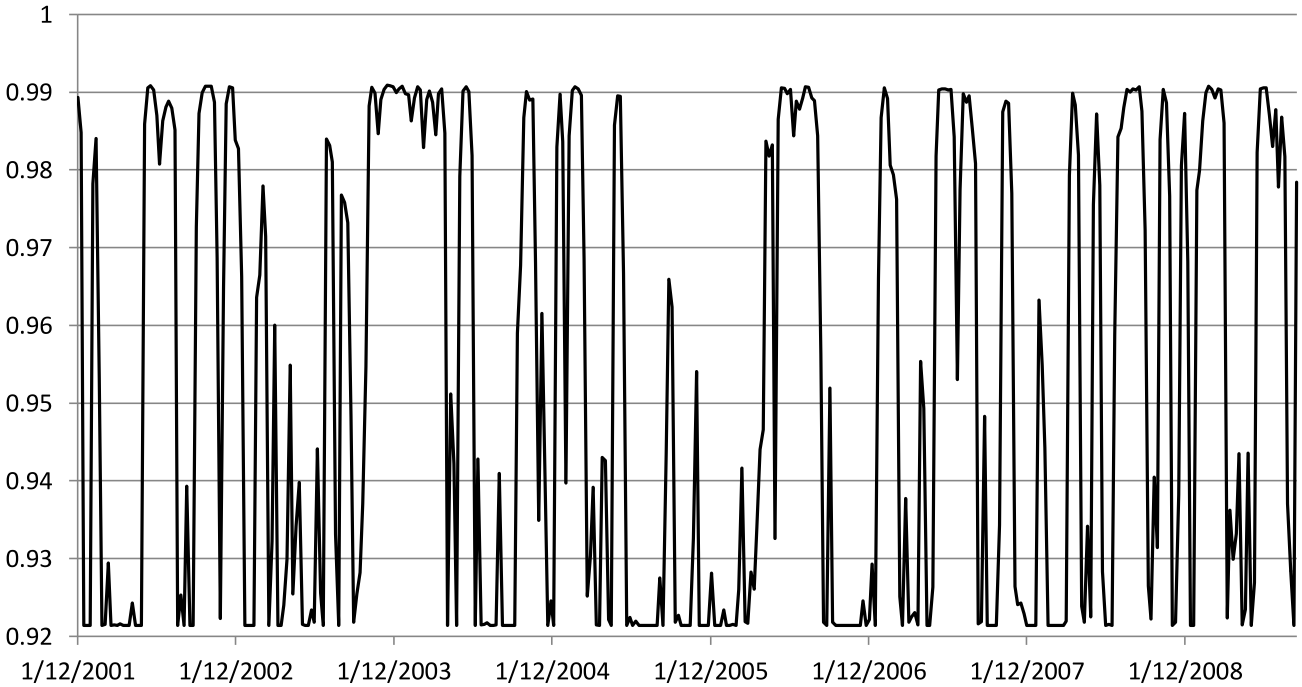
Hedging Effectiveness - In Sample

Model		Mean	Variance	Percent Reduction
Unhedged		60.3078	8,203.25	
Naive		45.3498	7,180.01	*12.47*
Simple	Regime 1	45.2343	7,646.20	6.79
	Regime 2	47.9037	6,652.04	18.91
	Combined	48.3630	6,327.54	*22.87*
RSDC	Regime 1	45.3940	8,032.70	2.08
	Regime 2	47.7006	6,816.72	16.90
	Combined	48.6968	6,735.89	*17.89*

Hedging Effectiveness - Out of Sample

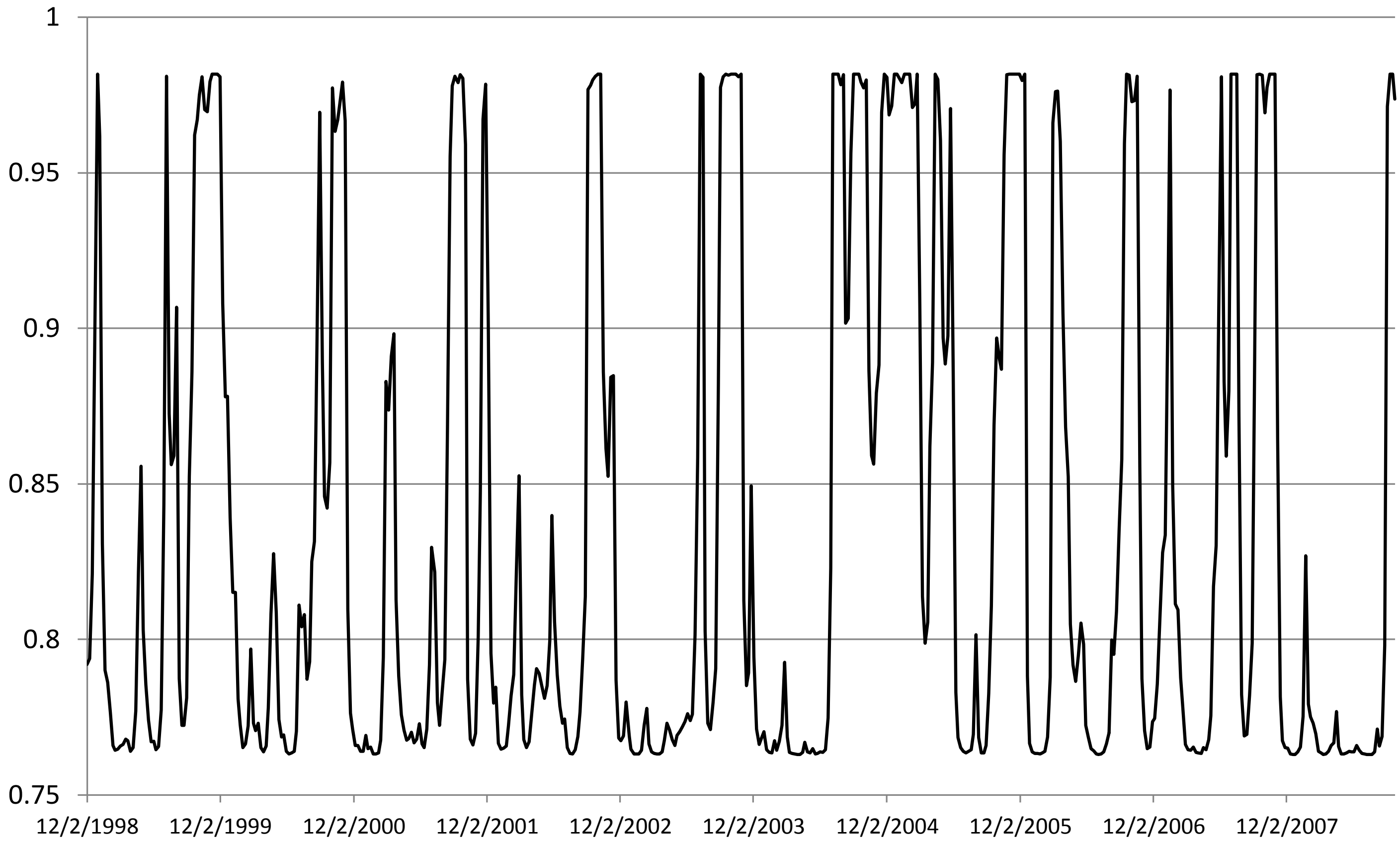
Model		Mean	Variance	Percent Reduction
Unhedged		34.0866	5,493.54	
Naive		81.6112	4,335.76	*47.15*
Simple	Regime 1	67.9204	4,073.47	50.34
	Regime 2	61.4032	3,829.27	53.32
	Combined	61.5694	3,809.54	*53.56*
RSDC	Regime 1	69.1458	4,227.04	48.47
	Regime 2	62.3559	4,028.08	50.90
	Combined	62.5578	3,994.88	*51.30*

Figure 1.



Dynamic Correlation for Weekly Soybean Cash & Soybean Futures Prices - Soybean Complex

Figure 2.



Dynamic Correlation for Weekly Soybean Meal Cash & Soybean Meal Futures Prices - Feedlot Operator