Do Elevators Need a Bigger Umbrella? The Economic Value to Agribusiness Firms of Improved Multi-Commodity Risk Management

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Introduction

The 2007-2008 commodity bull cycle was characterized by a steep upward price trend, weak basis levels, high volatility, and the drying-up of credit lines for agricultural operators. For example, the Wall Street Journal reported on August 17th 2008 that following the cotton synthetic futures price spike, "family-owned Canale Cotton Co., unwound its positions and bore a loss of some $2 million, family members confirm." In the case of grain elevators, the Bismarck Tribune reported on July 26th 2008 that "during the sharp run-up in commodities prices in February, it wasn't uncommon for grain elevators to have six-figure margin calls in a single day."

This paper asks: Do elevators need a bigger umbrella? Do agricultural operators need to change their risk management practices in light of the commodity bull cycle and subsequent price drop? And, what is the economic value of an improved understanding of optimal multi-product hedging? To answer these questions, we consider the general risk management problem of an agribusiness firm such as a grain elevator with access to a shipping port, e.g. on the Mississippi Gulf or Texas Gulf.

According to Wilson et al. (2006), the Gulf is the fastest-growing U.S. source of grain and oilseed exports. We assume the stylized grain elevator or agribusiness firm conducts business with the European Union and with Mexico, thus adding two sources of currency risk (foreign exchange uncertainty). We further account for finite credit lines by including loans necessary to take futures positions, and also include transaction costs for all positions initiated, changed, or lifted. We solve for the optimal solution set conditional on the elevator manager's objective (e.g., maximize utility, minimize downside risk, or avoid bankruptcy) and also on the time period. We estimate the models using data associated with periods before and during the recent commodity "boom-and-bust" cycle, and reserve data associated with the period after the commodity bull cycle to conduct out-of-sample model validation.

In this paper we ask: In light of the economic crisis and commodity "boom" and bust, do elevators and other agricultural operators need a bigger umbrella? Is there a nontrivial economic value to improved multivariate hedging, particularly if we allow for non-elliptical dependence structures? To this end, we consider the stylized problem of a grain elevator with import-export operations near the Gulf of Mexico. In this example, the joint risk management problem involves several grain and oilseed commodities as well as two sources of currency exchange rate risk (the Euro and the Real). We relax traditional assumptions to allow for highly non-elliptical dependence, using a kernel (empirical) copula, and the objective of minimizing downside risk (second lower partial moment). We consider three time periods: before the commodity bull cycle, during, and after.

The paper aims to make two main contributions. The practical contribution is to find out, through a stylized example, whether grain elevators and other agribusinesses likely need to change their risk management practices following the 2007-2008 crisis. The academic contribution is to determine whether, in a high-dimensional setting, relaxing traditional hedging assumptions leads to dramatically different conclusions, or not. Indeed the present eight-dimensional problem is fairly computationally challenging when the traditional assumptions of normality and variance-minimization are relaxed in favor of a non-elliptical copula-based joint distribution and downside risk-minimization.

Motivation

This paper is motivated by the price risk management challenges faced by grain elevators in recent years as outlined in the introduction. Elevators use a variety of price risk management strategies other than futures contracts. Furthermore, Kastens and Dhuyvetter (1999) found that hedging reduces risk but does not affect expected profits.

We consider the more general but stylized example of a Gulf of Mexico-region agribusiness operator with import-export business and one or more grain elevators for grain and oilseed inventory storage. The elevator buys and sells different grains and oilseeds products, namely corn, wheat, soybeans and crushed product: oil and meal.

Based on the USDA's FATUS reports, we assume the firm exports soybeans to the EU, corn and wheat to Mexico, and imports cocoa and canola. The full hedging problem therefore involves futures positions for several commodities and currency exchange rates.

Our main objective is to analyze in the general case the set of optimal risk management strategies for a multi-commodity, multi-currency operation when the dependence structure between the random variables is not necessarily elliptical (i.e., Normal). Recent findings suggest that the normality assumption should be rejected for all commodity futures (log) prices in the short to middle run (Chen, Lee, and Shrestha, 2008). Fackler and McNew (1993) show that optimal hedge ratios calculated in a multi-commodity or multi-product setting can be very different than those obtained from individual regressions.

Given the evidence of credit lines drying up in some regions, we pay special attention to transaction and financial costs of hedging. As a constraint, we define a maximum amount of credit available for the elevator to borrow as a loan with interest to be repaid, with the threat of illiquidity in the event that the credit maximum is reached. Transaction costs on all futures position changes are also included.

Research interest in optimal hedging has certainly waned, as a number of contributions cast doubt on the practical usefulness of sophisticated hedging models. For example, Lence

(1995) found that, under reasonable assumptions, the economic value from improved hedging is trivial. Moreover, in his review of the literature on multi-commodity hedging, Collins (2000) concurred, finding that multivariate hedging models offer hardly any improvement over old-fashioned, equal-and-opposite hedges.

However, our claim is that the results might be very different if we relax the assumption of an elliptical dependence structure in a multi-commodity setting. To this end, we describe the dependence between commodities and/or products using a kernel (empirical) copula. This nonparametric approach has the advantage of "letting the data speak for itself" which can be particularly useful if the dependence is strongly non-elliptical or possibly asymmetrical.

Furthermore, following the results of Lence (1995) and others, we relax the assumption that variance-minimization is the desired objective, and instead consider measures of expected shortfall relative to a target, which are more consistent with revealed preferences of agricultural operators (Collins, 2000). Specifically, we adopt as criterion the minimization of downside risk and formally, the second Lower Partial Moment. A recent empirical applications of the downside risk criterion for futures hedging (but only for the single-commodity case) is Mattos, Garcia and Nelson (2008). The authors find that the optimal hedging results can change substantially when downside risk is used as an objective criterion.

Data Sources

Business daily futures price data for corn, soybeans, and wheat are obtained from the Chicago Board of Trade (Chicago Mercantile Exchange, CME) through Datastream for the period 1/2000 to 4/2010. We sample the data weekly, using the Thursday observation when available, otherwise Wednesday. Corresponding weekly cash prices are obtained from the USDA-ERS and AMS for the appropriate geographical locations. Currency exchange rate spot and futures data are obtained from the CME through Datastream. Other relevant data is obtained from Texas A&M Agri-Life Extension.

Theoretical Model and Description of Variables

Assume a representative agribusiness grain and oilseed operation on the Mississippi Gulf. The choice of this location for our stylized example is based on reports from the USDA's Grain Inspection, Packers and Stockyards Administration according to which in 2009 grain elevators in the Mississippi Gulf were responsible for shipments of 56 million tons of grain and oilseeds, including corn, wheat and soybeans. For these commodities this region was the most economically important. In comparison, shipments from facilities in the Texas Gulf were 10 million tons of grain, but 85% of which was wheat. The agribusiness operator's problem involves hedging the purchase, storage and sale of 100,000 bu of corn, soybeans and wheat:

- At period t=0, it takes long futures positions to hedge the planned cash purchase of corn, soybeans and wheat;
- At period t=1, it offsets the long futures position, purchases cash the commodities and places them in storage, and additionally it initiates short futures positions in all three commodities as well as in Euro:USD and Peso:USD exchange rates to protect itself against depreciation of those currencies;
- At period t=2, it offsets all futures positions and sells cash the commodities to business partners in the EU and Mexico in the local currencies.

Then, the net profit from the operation can be expressed as:

$$\pi(\mathbf{h}) = \sum_i Q_i \left((\tilde{p}_2^i - \tilde{p}_1^i) + h_0^i(\tilde{f}_1^i - f_0^i) - h_1^i(\tilde{f}_2^i - \tilde{f}_1^i) - \tilde{r}(h_0^i, h_1^i) - w(Q) \right) \quad (1)$$

where superscripts i refer to commodity i ={corn, soybeans, wheat}, subscripts 0, 1 and 2 indicate the periods as defined above, p are cash prices, f are futures prices, Q are quantities, h

are hedge ratios, *r* is the stochastic financing cost including costs of margin calls, and *w* is the non-stochastic cost of storage. Tildes denote stochastic variables. Financing cost *r* is a function of the futures positions and depends on the cost of margin calls. Storage cost *w* is proportional to quantities *Q*. The signs in (1) are set so that $\mathbf{h} = \{1,1,1\} = \mathbf{1}$ corresponds to equal and opposite (naïve) hedges, and $h^j < 0$ corresponds to speculation in commodity *j*. Note also that $\mathbf{h} = \{0,0,0\} = \mathbf{0}$ corresponds to no hedging (baseline situation).

This stylized problem assumes that 100,000 bu of each commodity is stored for a period of several weeks during the storage season. It is assumed no old crop is carried over to the new season. It is also assumed there is no storage cost uncertainty and therefore that storage cost is independent of commodity prices. The assumption that $Q_{corn} = Q_{soybeans} = Q_{wheat}$ is only made to simplify the problem and focus on the questions of interest in this paper. It has been shown elsewhere that hedge ratios are indeed sensitive to the relative monetary value of different commodity inventories held by the operator (e.g., Fackler and McNew, 1993).

The scenario is greatly simplified but maintains the key issues of price risk management for multiple commodity transactions and exchange rates. The relevant variables are spot and futures corn, wheat and soybeans prices, as well as spot and futures Euro:USD and Peso:USD exchange rates. To find out whether grain elevators should change their price risk management strategies following the end of the commodity "bull cycle" of 2007-2008, we consider three periods for the analysis relating to the commodity bull cycle:

- Before: 1/2000-12/2005
- During: 1/2006-8/2008
- After: 9/2008-4/2010

To illustrate changes in market volatility, that plays a key role in the determination of optimal hedges, consider the following table which presents the annualized volatility for each commodity or exchange rate, based on the standard deviation of weekly price or exchange rate log-returns.

- For corn futures, volatility increased from 24% before to 33% during and 43% after
- For soybean futures, volatility was about 25% before and during, but increased to 36% after
- For wheat futures, volatility increased from 24% before to 33% during and 36% after
- For corn cash prices, volatility increased from 25% before to 35% during and 38% after
- For soybean cash prices, volatility increased from 30% before to 32% during and 40% after
- For wheat cash prices, volatility increased from 22% before to 33% during but decreased to 30% after
- For the Euro-to-USD exchange rate futures, volatility decreased from 10% before to 7% during, then increased to 15% after
- For the Mexican Peso-to-USD exchange rate futures, volatility decreased from 9% before to 6% during, but increased to 19% after
- For the Euro-to-USD spot exchange rate, volatility decreased from 10% before to 7% during, then increased to 15% after
- For the Mexican Peso-to-USD spot exchange rate, volatility decreased from 8% before to 7% during, then increased to 19% after

Margin Risk

When futures price volatility is high, the likelihood that a hedger will receive a margin call increases (McKenzie and Kunda, 2009). For each sample period, we evaluate the margin risk and cost assuming that the interest rate increases with the size of the credit line. Since margin costs affect the expectation and variance of revenue and profit, they affect the optimal futures positions (Brorsen, 1995).

Empirical Methodology

Recently, an empirical literature has emerged that applies downside risk measures, specifically the family of lower partial moment (LPM) criteria (Fishburn (1977)), in order to relax traditional hedging assumptions. Experimental evidence suggests that the LPM family is better suited for the type of risk preferences typically exhibited by agricultural producers and commodity hedgers (Unser (2000)). An *n*th-order lower partial moment (LPM_n) of a random variable $\tilde{\pi}$ relative to a target level $\bar{\pi}$ is formally defined as

$$LPM_n = \int_{-\infty}^{\bar{\pi}} (\bar{\pi} - \tilde{\pi})^n \, dF(\tilde{\pi})$$

where $F(\tilde{\pi})$ is the distribution function of $\tilde{\pi}$. The LPM_n criterion is known to be consistent with the $(n+1)^{th}$-order stochastic dominance (Ingersoll (1987)) and thus with expected utility maximization for a wide class of utility functions (e.g. Levy (1998)).

Optimal Hedge Ratios

The random variables of interest in (1) are the spot and futures prices at periods 1 and 2, which are not known at initiation (period 0). The operator's objective is then to select the optimal hedge ratios **h*** so as to minimize the measure of risk defined on π:

$$LPM: \mathbf{h}^* = \arg\min_{\mathbf{h}} \; LPM_2(\bar{\pi}, \mathbf{h}) = \arg\min \int_{-\infty}^{\bar{\pi}} \left[\bar{\pi} - \pi(\mathbf{h})\right]^2 dF(\pi(\mathbf{h})), \qquad (2)$$

where π is defined in (1) and the target $\bar{\pi}$ is selected as the expected profit without hedging, i.e. $\bar{\pi} = \mathbf{E}\pi(\mathbf{0})$.

$$EU: \mathbf{h}^* = \arg\max_{\mathbf{h}} \; U = \int_{-\infty}^{\infty} \pi(\mathbf{h}) dF(\pi(\mathbf{h})) - \lambda \, \mathrm{Var}(\pi(\mathbf{h})),$$

Kernel Copula

To solve the optimization problems in (2) requires knowledge of the distribution of π. The latter is determined by the joint distribution of several random variables in (1). Although multivariate normality is often assumed to simplify the computational burden, Chen et al. (2008) have found that this hypothesis should be rejected for commodity futures price data.

A more flexible approach to model the joint distribution of random variables is the copula (Nelsen 2006). In the empirical literature in finance, however, specific copula parametric forms are often arbitrarily selected. Instead, in this paper we consider a non-parametric estimation of the copula using using multivariate kernel smoothing (Charpentier, Fermanian, & Scaillet (2007)). This approach has the advantage of allowing the dependence structure between the random variables to be data-driven. In practice, implementing the kernel density approach requires overcoming challenges such as how to determine the appropriate bandwidth and how to estimate probabilities at the tails of the distribution.

The problems in (2) are solved numerically and the Monte Carlo approach is used to compute the integrals in (2). Using the historical realizations of shocks $\left\{\varepsilon_P^i, \varepsilon_F^i\right\}$ computed from the historical cash and futures prices, we estimate (i) the marginal probability density functions of each shock using the kernel density approach and (ii) the copula density of the multiple-dimensional joint distribution of shocks based on the approach of Charpentier et al. (2007). From the estimated copula density are generated 125 series of 10,000 Monte Carlo draws. The draws from the copula are converted to draws from the joint distributions of shocks by applying the inverse marginal density transformation, i.e., where $G_i(\cdot)$ are marginal cumulative density functions corresponding to g_i. Finally, the generated series of shocks are converted to realizations of cash and futures prices at the hedge expiration dates by multiplying them by the average cash and futures prices at initiation over the sample period.

The resulting simulated cash and futures prices are used to compute the net profit in (1) for any given vector of hedge ratios **h.** The revenue target in the LPM criterion is set equal to the average of the no-hedge revenues calculated for each date in the sample. Given the net profits corresponding to Monte Carlo draws, the LPM_2 criterion and the variance are calculated as the corresponding sample estimates. The optimal hedge ratios are computed using the Nelder-Mead derivative-free method (Miranda & Fackler (2002)).

Results

All computations were performed in MATLAB R2008b. Each series of 10,000 Monte Carlo draws was used to compute the optimal hedge ratios under the LPM_2 criteria, and the procedure was repeated 125 times.

Benchmark Results: OLS Hedges

As a baseline we estimate simple OLS hedge ratios (i.e., assuming normality) against which we can compare the jointly-estimated downside risk hedge ratios where the normality assumption is relaxed. The results presented in table 1 suggest that for corn the naïve OLS hedge ratio increased from about 0.47 to about 0.70 during the commodity bull cycle and dropped to about 0.55 afterward. Similarly, the OLS hedge ratio for soybeans increased from 0.56 before to 0.69 during the commodity bull cycle and decreased to 0.65 afterward. The case of wheat is different, however. The OLS hedge ratio decreased from 0.39 before to 0.12 during the commodity bull cycle (the latter H* not statistically different from zero), and increased to 0.23 afterward. Lastly, OLS hedge ratios for exchange rates are all about 1 and did not change very much, with the exception of the Peso:USD hedge ratio increasing from 0.84 before to 1.04 during the commodity bull cycle.

Table 1: Naïve OLS hedge ratios, by sample period and commodity or exchange rate

Period	Corn	Soybeans	Wheat	Euro:USD	Peso:USD
1/2000-12/2005	0.472	0.562	0.394	0.955	0.842
	(0.0453)	(0.0427)	(0.0436)	(0.0134)	(0.0171)
1/2006-7/2008	0.696	0.692	0.125	0.961	1.040
	(0.0727)	(0.0715)	(0.0961)	(0.0160)	(0.0244)
8/2008-4/2010	0.555	0.648	0.232	0.998	0.992
	(0.0838)	(0.0697)	(0.089)	(0.0150)	(0.0183)

Note: White robust standard errors are in brackets.

Jointly-estimated Downside Risk Hedge Ratios

If the hedge ratios are calculated in the multi-commodity LPM_2 framework described earlier in which the distribution is allowed to be determined non-parametrically using a kernel copula, the results, presented in table 2, change substantially. In the first sample period, the hedge ratios for corn and wheat are about 1, but for soybean it is about 0. In the second sample period, corresponding to the commodity bull cycle, the hedge ratio falls to about 0.92 for corn and 0.75 for wheat but increases to 0.258 for soybeans. Finally, in the last sample period, the hedge ratios are nearly the same as they were in the first period: close to 1 for corn and wheat, but close to 0 for soybeans. Exchange rate LPM_2 hedge ratios are omitted from the table as they are not substantially different from the OLS hedge ratios.

Table 2: Jointly-estimated LPM_2 hedge ratios using a kernel copula-based distribution, according to sample period and commodity

Period	Corn	Soybeans	Wheat
1/2000-12/2005	0.975	-0.0125	1.011
1/2006-7/2008	0.918	0.258	0.755
8/2008-4/2010	1.041	-0.0570	0.967

The findings confirm previous empirical evidence, for other portfolios of commodities, suggesting that optimal hedge ratios can change dramatically when they are estimated jointly (Fackler and McNew, 1993), and also when downside risk is used as a criterion instead of variance minimization (Mattos, Garcia and Nelson, 2008).

Conclusion

A number of grain elevators and other agribusiness operations struggled during the commodity bull cycle of 2006-2008 as traditional market-based risk management instruments failed to perform as expected. In this paper, we ask whether during volatile market periods substantially different futures strategies may be necessary. We relax the traditional assumptions of variance minimization and joint normality of price innovations and estimate jointly-determined futures hedge ratios for an agribusiness operator facing multiple commodity price and exchange rate risks. It is assumed the operator wishes to minimize only downside risk when selling commodities (or upside risk when buying commodities). The joint distribution is captured non-parametrically using a kernel copula to allow for the possibility of non-elliptical empirical distributions. Using data from 2000-2010, we contrast results across three sample periods: before, during and after the commodity bull cycle. We also present "naïve" OLS hedge ratios for purposes of comparison.

The results suggest, first, that when optimal hedge ratios indeed change significantly when traditional assumptions are relaxed, and second, that optimal hedging strategies changed during the commodity bull cycle but, for the period after 7/2008, appear to be similar to what they were in the late 1990s and early 2000s. Further work, however, should be done to fully evaluate the importance of margin risk in light of the extended periods of increasing (2006-08) and decreasing (2008-09) prices during which time the cost of margin calls can become prohibitive (e.g., McKenzie and Kunda, 2009).

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