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A Comparison of Hedging Strategies and Effectiveness for Storable and Non-Storable Commodities

by

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A Comparison of Hedging Strategies and Effectiveness for Storable and Non-Storable Commodities

This research questions whether the hedging potential of a futures market differs between storable and non-storable commodities. The relationship between asset storability and hedging effectiveness was examined using five years of daily cash and futures data for eight commodities. Three hedge ratios were estimated for each commodity – the naive (1:1) hedge ratio, the OLS hedge ratio, and either the BEKK-GARCH hedge ratios or the ECM-GARCH hedge ratios depending on whether or not the cash and futures price series were cointegrated. Results indicate that the futures market for livestock performed poorly in its hedging function compared to the futures market for other commodities; however, there was insufficient evidence to conclude that this holds for all non-storable commodities.

Key Words: Commodity futures markets, asset storability, GARCH hedge ratio, OLS hedge ratio, hedging effectiveness, and portfolio variance.

INTRODUCTION

It has been said that commodity futures markets hold economic merit if they provide a valid pricing function or hedging potential (Skadberg & Futrell, 1966). The effect of storability on the pricing function of commodity futures markets has been investigated by many author over several decades including Yang, Bessler and Leatham (2001), Zapata and Fortenbery (1996), Covey and Bessler (1995), and Leuthold (1974); however, the effect of commodity storability on the hedging mechanism provided by commodity futures markets, specifically its effectiveness, has not been widely studied.

Yang and Awokuse (2003) were among the first to investigate whether hedging effectiveness differs between non-storable and storable commodities. Specifically, they questioned whether hedging effectiveness for storable commodities outperformed non-storable commodities. Eight agricultural commodities were included in the study; five storable commodities (corn, soybeans, wheat, cotton, and sugar) and three non-storable commodities (lean hogs, live cattle, and feeder cattle). Five years of daily data commencing in January of 1997 were used to estimate the bivariate ECM-GARCH hedge ratios. The effectiveness of the hedge ratios were compared using a measure of variance reduction. The results indicated that, in comparison to the five storable commodities, hedging effectiveness was very poor for cattle and moderately poor for feeder cattle. On the other hand, the hedging effectiveness for lean hogs was at par with the storable commodities. The authors concluded that the results provided evidence that hedging effectiveness for storable commodities outperformed non-storable commodities.

Choudhry (2009) extended Yang and Awokuse's (2003) research to include four time-varying hedge ratios. Seven agricultural commodities were included in the study; five storable commodities (corn, soybeans, wheat, cotton, and sugar) and two non-storable commodities (live cattle and lean hogs). Twenty-four years of daily data commencing in August of 1980 were used to estimate four versions of the GARCH model – bivariate GARCH, bivariate BEKK GARCH, bivariate GARCH-X, and bivariate BEKK GARCH-X. The time-varying hedge ratios were compared using the reduction in the portfolio variance. Hedging effectiveness was also compared for two out-of-sample forecasts using the same method as the within-sample hedge ratio. Overall, the hedge ratios computed using the GARCH-X model performed the best. Among other findings, the author concluded that the results did not provide evidence that hedging effectiveness for storable commodities was any different than for non-storable commodities, contradicting the findings of Yang and Awokuse (2003).

This research questions whether the hedging potential of a commodity futures market differs between storable and non-storable commodities. The focus of this research is on operational hedging, with effectiveness assessed using a variance reduction measure. Similar to Yang and Awokuse (2003), this research estimated the hedge ratios for all eight commodities using the traditional OLS model and a GARCH model. Additionally, the naive hedge ratio (i.e., one futures position for every cash position) is considered. After estimating each of the hedge ratios, the commodities are ranked according to hedging effectiveness to see how the hedging mechanism provided by commodity futures markets for non-storable commodities performs in comparison to storable commodities. This research also compares the effectiveness of the OLS hedge ratio with that of the GARCH hedge ratios for each commodity.

The objectives of this research are to add to the findings of Yang and Awokuse (2003) and Choudhry (2009) in four ways – (1) to replicate their methods using current data which includes the recent period of extreme market (price) volatility; (2) to expand their analysis beyond basic agricultural commodities; (3) to increase the range in storability between the most and least storable of the commodities selected (i.e., gold is at the extreme positive end of the storability scale whereas live hogs are at the extreme negative end); and (4) to expand their definition of storability, allowing storability to be an ordinal rather than a binary characteristic.

The remainder of this chapter is organized as follows. The next section describes the data and commodities. The third section presents and explains the storability ranking. The fourth section presents the empirical methods employed including tests for stationarity, unit roots, and cointegration, estimates of the OLS and the GARCH hedge ratio, and measures of hedge ratio effectiveness. The empirical results are summarized and discussed in the fifth section. The sixth section concludes and provides some areas for further research.

DATA DESCRIPTION AND COMMODITY INFORMATION

Five years of daily cash and futures data commencing November 16th, 2003 have been extracted from the Commodity Research Bureau Database using the PowerGen Synthetic Data Generator for each of the eight commodities. The closing price for the most active nearby futures contract based on volume traded was used to generate a continuous futures price series with a rollover period 14 days prior to the expiry of the contract. All of the data is back-adjusted. Dates without both a cash and futures price were deleted from the data sample. This adjustment resulted in a slight variation in number of price observations for commodities traded on different exchanges. The number of observations ranged between 1,252 and 1,257. Specific details on each of the eight commodity contracts, a brief explanation of the end uses and a plot of the raw cash and futures price series follow.

The first commodity of interest is gold. Its electrical conductivity, malleability, and resistance to corrosion make it useful in the manufacturing of electronic products and equipment, including computers, telephones, cellular phones, and home appliances. Gold's reflective powers shield spacecrafts and satellites from solar radiation and focus light energy in industrial and medical lasers. Because gold is biologically inactive, it is used in medical and dental treatments. Gold futures trading is conducted for delivery during the current calendar month, the next two calendar months, any February, April, August, and October falling within a 23-month period, and any June and December falling within a 60-month period beginning with the current month. The trading unit is 100 troy ounces with prices expressed in US dollars per troy ounce (New York Merchantile Exchange). A miNY futures contract is also available, with the trading unit being 50 troy ounces. Gold is very storable in safe, internationally accepted units.

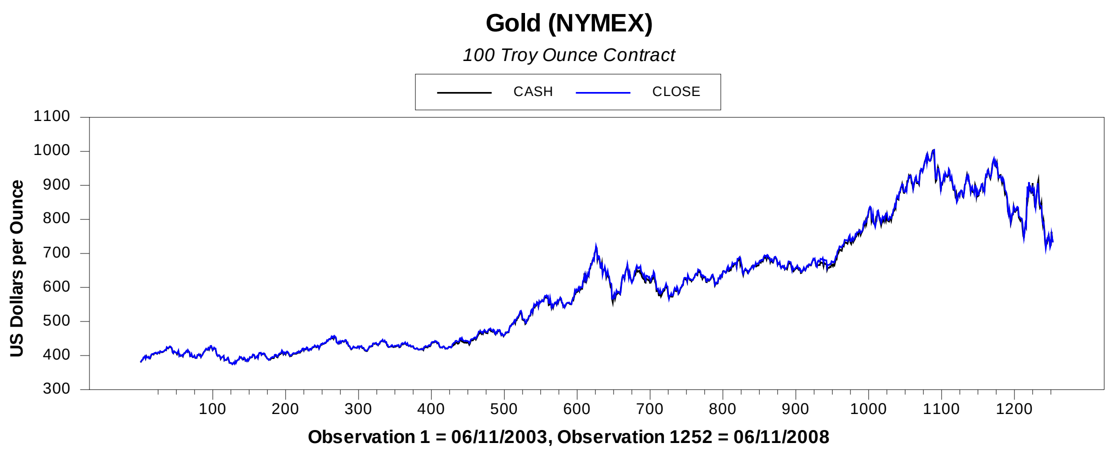


Figure 1. Gold Price Series

The second commodity of interest is silver. Silver is used in the photography industry, the jewellery industry, and the electronic industry. Newly mined metal is the primary source for silver. Secondary sources include coin melt and scrap recovery. Silver futures trading is conducted for delivery in January, March, May, July, September, and December. The trading unit is 5,000 troy ounces with prices expressed in US cents per troy ounce. A miNY futures contract is also available, with the trading unit being 2,500 troy ounces (New York Mercantile Exchange). Silver is very storable, although the cost of storing silver per dollar value is higher than gold. Silver is considered to be more storable than wheat and less storable than gold for the purpose of this research.

Figure 2. Silver Price Series

The third commodity of interest is wheat. Wheat futures trade in 5,000 bushel lots in cents per bushel. Grades deliverable against a wheat futures contract are No. 2 Soft Red Winter, No. 2 Hard Red Winter, No. 2 Dark Northern Spring, and No. 2 Northern Spring at par; No. 1 Soft Red Winter, No. 1 Hard Red Winter, No. 1 Dark Northern Spring and No. 1 Northern Spring at 3 cents per bushel over contract price (CME Group). Wheat is very storable under conditions of careful control of moisture level, temperature and insect infestation.

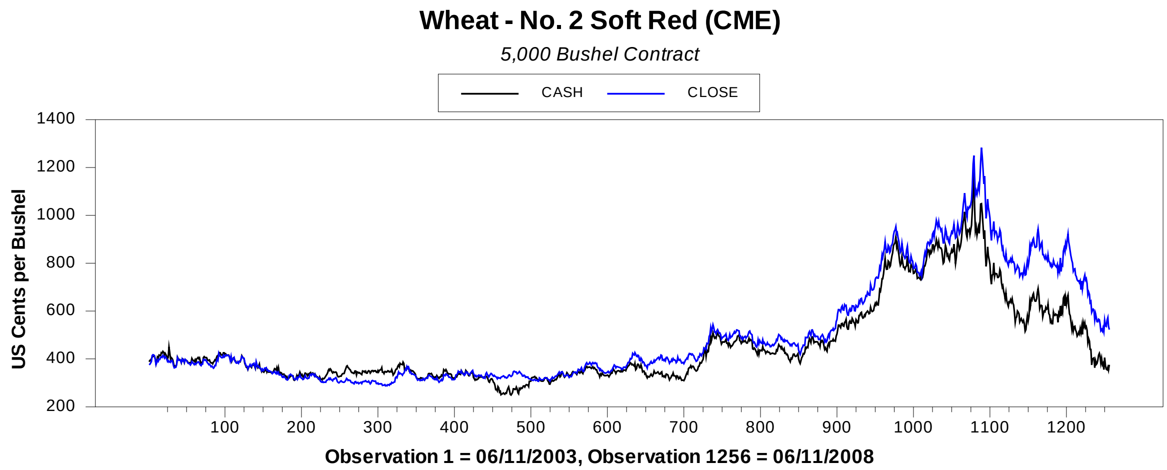


Figure 3. Wheat Price Series

The fourth commodity of interest is corn. Corn futures trade in 5,000 bushel lots in US cents per bushel. Grades deliverable against a corn futures are #2 Yellow at contract price, #1 Yellow at a 1.5 cent/bushel premium, and #3 Yellow at a 1.5 cent/bushel discount. Corn is very storable under conditions of careful control of moisture level, temperature and insect infestation (Chicago Board of Trade). Drying of corn with heat and aeration is often necessary to reduce its moisture content at harvest to a suitable level for long-term storage.

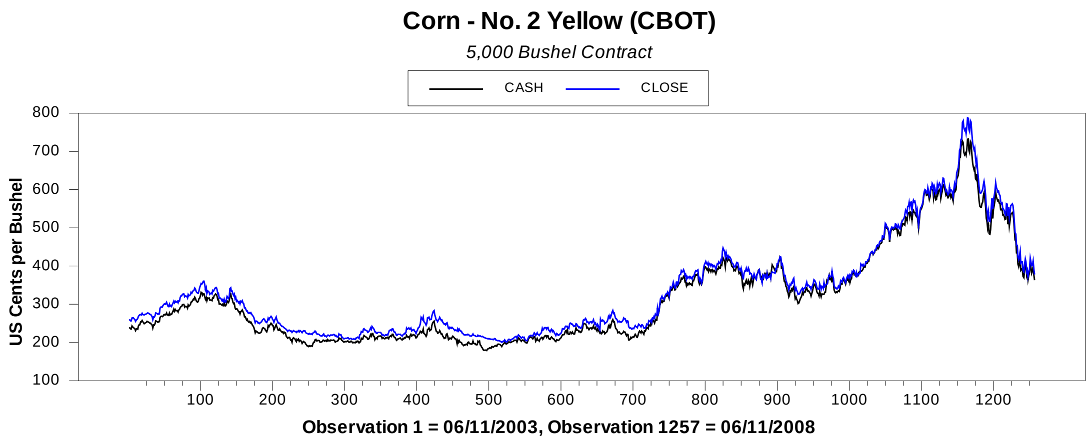


Figure 4. Corn Price Series

The fifth commodity of interest is soybean meal. Soybean meal futures are traded in US$/short ton (2,000 pounds), and are settled by physical delivery. Futures months are January, March, May, July, August, September, October, and December (Chicago Board of Trade). Soybean meal is a residual product of soybeans after the oil is extracted, and is an important source of protein (48%) for livestock feeds. The two major factors affecting storability of soybean meal are moisture content and temperature. If these factors are maintained within acceptable ranges, soybean meal can be stored without much deterioration in quality for up to three years. However, lack of flowability makes soybean meal a poor candidate for bulk storage in hopper-bottom bins. For this reason, crushers prefer to market soybean meal shortly after production making it less storable than wheat or corn.

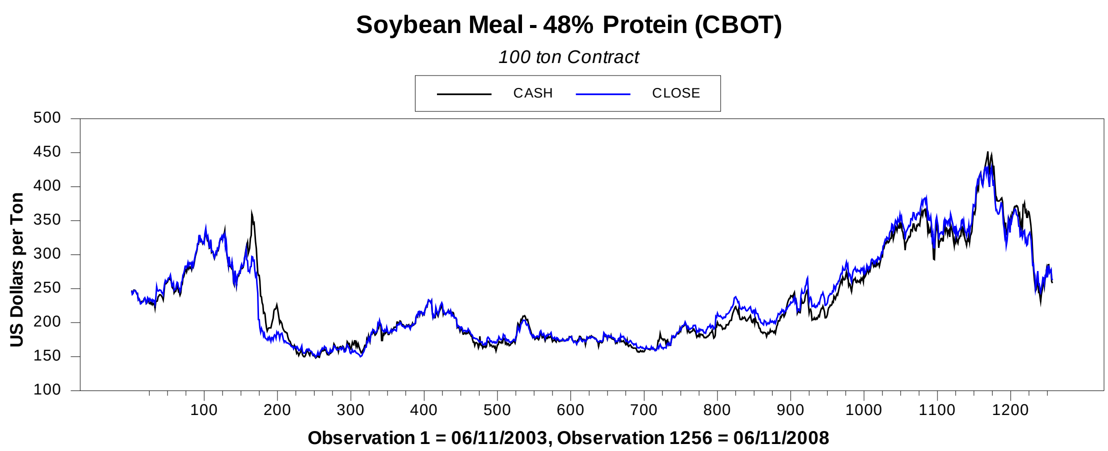


Figure 5. Soybean Meal Price Series

The sixth commodity of interest is feeder cattle. Feeder Cattle are animals that are six to ten months old, weighing between 650 and 849 pounds, and on their way to feedlots to be finished into "fed" cattle. The fact that they are in-stream in their growth life leaves a fairly narrow window in terms of valuation making them relatively non-storable commodities. Futures months are January, March, April, May, August, September, October, and November. Contract size is 50,000 lbs and unit of trade is US cents per pound (CME Group).

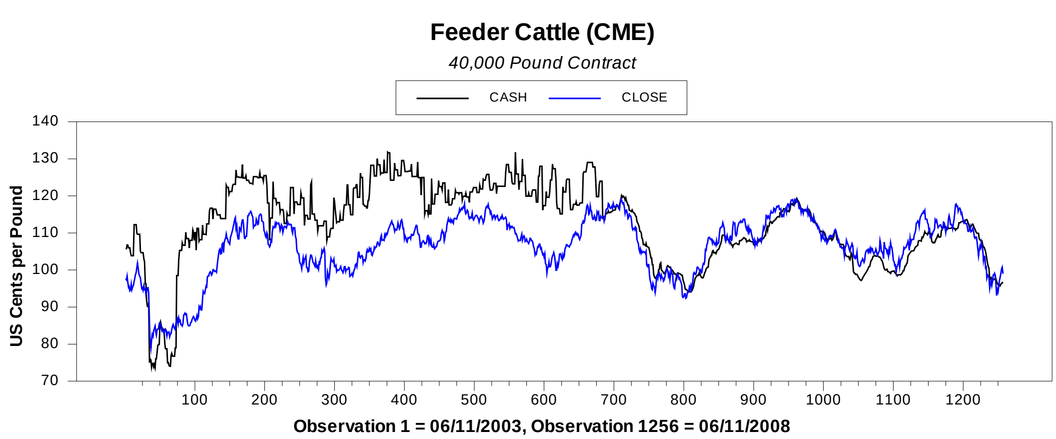


Figure 6. Feeder Cattle Price Series

The seventh commodity of interest is live cattle. When live cattle futures were introduced in 1964, the concept of trading futures on a live and non-storable commodity was revolutionary. Despite early questions, live cattle futures have proved to be a liquid market with strong trading volume. Live cattle are slaughter-ready animals at about 1,250 pounds live weight or 750 pounds carcass weight. They have normally been in a feedlot for about five months from the time they are considered feeder cattle. Contracts are 40,000 pounds, traded in US cents per pound with futures months of February, April, June, August, October, and December (CME Group).

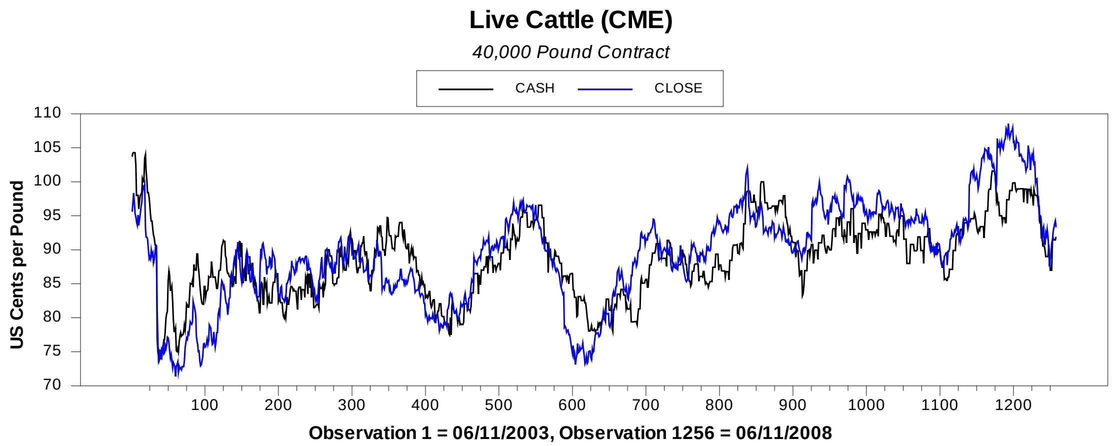


Figure 7. Live Cattle Price Series

The last commodity of interest is lean hogs. The Chicago Mercantile Exchange has traded lean hog futures since 1997. Prior to that hog futures were traded on a live weight basis. Hogs cut-out at about 80% so a lean hog represents about 80% of the weight of a live hog. Contract size for lean hog futures are 40,000 pounds which represents the approximate weight of a semi-trailer of lean hogs (about 200 animals). Trading months are February, April, May, June, August, October, and December (CME Group). Lean hog futures are cash settled. Hogs are moved into finisher barns at about 8 weeks of age. They are in the finisher barns for about 16 weeks at which time they reach slaughter weight. Grading grids place severe discounts on market hogs outside ideal weight ranges so cash hogs are shipped during a one-week window, making them non-storable.

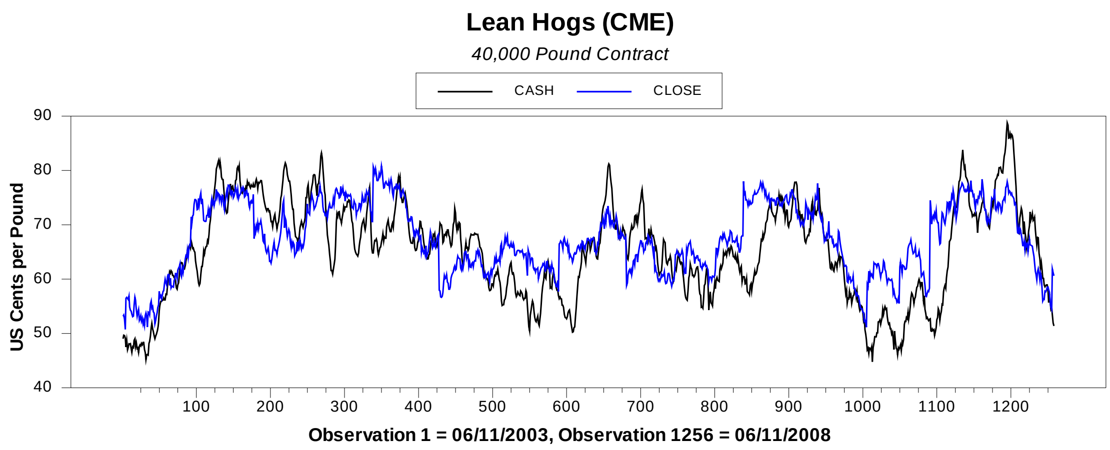


Figure 8. Lean Hogs Price Series

STORABILITY RANKING

A storable commodity can be defined as a commodity that does not easily spoil and does not cost a large deal of money to store (Covey & Bessler, 1995). Using this definition, some commodities can easily be classified as storable (i.e., gold, honey, and silver) while some commodities can easily be classified as non-storable (i.e., live hogs, milk, and electricity). However, not all commodities can be classified this easily (i.e., soybean meal, untreated lumber, and sunflower seed oil) because the storability of an asset is not a binary characteristic, but rather a continuous characteristic with a continuum running from zero to infinity, with zero being perfectly storable and infinity being perfectly non-storable (Covey & Bessler, 1995).

The commodities included in the study were carefully selected so that they would span the storability continuum. It was not a challenge to select a suite of commodities that fell into the storable end of the spectrum; however, it was a challenge to select a suite of commodities that fell into the non-storable end. Non-storable commodities considered include orange juice, milk, electricity, boiler chickens, eggs, feeder cattle and soybean meal. Feeder cattle and soybean meal were selected by default because daily cash and futures price data was not readily available or did not exist over the time period of interest for the remaining commodities.

To incorporate the continuous nature of storability into the research question the commodities of interest were ranked according to storability, allowing storability to be an ordinal characteristic. In addition to the information presented in the preceding section, the rankings have been made using information from interviews with industry experts (Nolting, 2009) (Grant, 2009). The relative storability rankings for each of the eight commodities of interest are as follows:

1. Gold
2. Silver
3. Wheat
4. Corn
5. Soybean Meal
6. Feeder Cattle
7. Live Cattle
8. Lean Hogs

The storability ranking is used to compare the hedging effectiveness of storable and non-storable commodity futures markets by comparing both the OLS and GARCH hedge effectiveness ranking with the storability ranking to see if similarities exist.

EMPIRICAL METHODOLGY

This section provides a detailed explanation of the empirical methodology including econometric tests and the Regression Analysis Time Series (RATS) program code used to perform the empirical econometric tests. The empirical methodology has been conducted in the method outlined for each of the eight commodities. The complete results are presented for one storable commodity (wheat) and one non-storable commodity (live cattle). The results for the remaining commodities are summarized in the results section; however, additional results can be obtained from the authors upon request. In all cases, a logarithmic transformation has been made to the data prior to conducting the empirical methodology and will be referred to as the price series throughout the remainder of this chapter.

Two standard tests have been selected to evaluate the stationarity of the (logged) price series; the Augmented Dickey Fuller (ADF) test (Dickey & Fuller, 1979) (Dickey & Fuller, 1981) and the KPSS test (Kwiatkowski, Phillips, Schmidt, & Shin, 1992). Both the ADF and KPSS test have been estimated with a constant, and a constant and trend. When the price series was found to be I(1) the same test was performed on the differenced price series to determine whether the price series was first difference stationary.

The program file in RATS selected to conduct the ADF test is uradf.src. The hypothesis for the ADF test is H_0: The series contains a unit root (ie., $\beta = 0$) against Ha: The series does not contain a unit root (ie., $\beta < 0$). The critical values for the calculated test statistic were calculated following Hamiltonian (1994). The maximum lag length was set at 11, which was calculated by rounding up the cube root of the sample size (i.e., $1{,}257^{1/3} = 8.128$). Three methods were used to determine the optimal lag length – the minimization of the Akaike Information Criterion (AIC), the minimization of the Schwarz Bayesian Information Criterion (BIC) and the reduction method. The results are presented in Table 1.

Table 1. ADF for unit root test

		Wheat - No. 2 Soft Red (CME)				Live Cattle (CME)		
		log(C)	Δlog(C)	log(F)	Δlog(F)	log(C)	log(F)	Δlog(F)
C	AIC	-1.2440	-22.7985**	-0.9947	-16.1821**	-3.4690**	-2.7035	-32.9044
	BIC	-1.3746	-38.1919**	-1.0441	-35.3573**	-4.2854**	-2.7035	-32.9044
	RDTN	-1.2440	-9.6798**	-0.9947	-17.1391**	-3.7029**	-2.4691	-13.3776
C&T	AIC	-1.2837	-22.7957**	-1.8258	-16.1756**	-4.4215**	-4.0434**	-32.8982
	BIC	-1.4826	-38.1819**	-1.5628	-35.3441**	-5.2589**	-4.0434**	-32.8982
	RDTN	-1.2837	-9.6855**	-1.8258	-17.1321**	-4.6868**	-4.0434**	-13.3812

Significance at $\alpha = 0.05$ denoted by **
C – Constant C&T – Constant and Trend
Note: There is no result for Δlog(C) because the null hypothesis is rejected in all cases for log(C).

The program file in RATS selected to conduct the KPSS test is kpss.src. The hypothesis for the KPSS test is H_0: The series is stationary against Ha: The series is not stationary. The maximum lag length was set at 23, which was calculated by rounding up $t = 12\left(\frac{T}{100}\right)^{1/4}$ (Kwiatkowski, Phillips, Schmidt, & Shin, 1992). The results are presented in Table 2.

Table 2. KPSS test for Stationarity

		Wheat - No. 2 Soft Red (CME)				Live Cattle (CME)			
		log(C)	Δlog(C)	log(F)	Δlog(F)	log(C)	Δlog(C)	log(F)	Δlog(F)
C	Lags=0	75.057*,**	0.130	97.881*,**	0.168	31.876*,**	0.068	55.794*,**	0.066
	Lags=23	3.203*,**	0.169	4.134*,**	0.169	1.614*,**	0.100	2.534*,**	0.060
C&T	Lags=0	15.047*,**	0.130	18.944*,**	0.174**	3.089*,**	0.032	2.702*,**	0.047
	Lags=23	0.671*,**	0.170**	0.839*,**	0.176**	0.171**	0.048	0.135	0.043

Significance at $\alpha = 0.025$ and 0.05 denoted by * and ** respectively
C – Constant C&T – Constant and Trend

Before moving on to the next step in the empirical methodology, an additional unit root test, namely the one-break unit root test by Lee and Strazicich was performed (2004). The hypothesis for the one-break unit root test is H_0: The series contains a unit root in the presence of a structural break against Ha: The series does not contain a unit root in the presence of a structural break. The rational for conducting the one-break unit root test can be seen in the raw data plots. Most of the series exhibit a clear structural break near the end of the data series, which coincides with January of 2008. The only commodity that exhibited two structural breaks was soybeans. For this commodity the two-break unit root test by Lee and Strazicich (2003) replaced the one-break unit root test.

The program file in RATS selected to conduct the one-, and two-break unit root test is lsunit.src. Two unit root tests were conducted for each commodity. The first allowed for a change in level, and the second allowed for a change in the level and trend. The number of lags included in the model was chosen according to a general to specific method and structural breaks were limited to ninety percent of the data points, excluding five percent from each the beginning and the end of the data series. The critical values for the one-break unit root tests were taken from Lee and Strazicich (2004) and the critical values for the two-break unit root tests were taken from Lee and Strazicich (2003). The results are presented in Table 3.

Table 3. One-break unit root test

	Wheat - No. 2 Soft Red (CME)				Live Cattle (CME)			
	log(C)	Δlog(C)	log(F)	Δlog(F)	log(C)	Δlog(C)	log(F)	Δlog(F)
L	-0.0127	-1.0583**	-0.0115	-0.9809**	-0.352	-1.1953**	-0.0206	-0.9659**
L&T	-0.0032	-0.3892**	-0.0027	-0.4880**	-0.0123	-1.2067**	-0.0095	-0.3829**

Significance at 0.05 denoted by **
L –Level L&T – Level and Trend

The next step in the empirical methodology was to determine whether the cash and futures price series were cointegrated. Two series are said to be cointegrated if they are tied together by a long run relationship. The cash and futures price series are cointegrated if both the cash and futures price series are I(d) and ε is I(d-1). The Engle-Granger Test for Cointegration was used to test whether the cash and futures price series were cointegrated. The program file in RATS selected to conduct the test is egtest.src. The critical values developed by MacKinnon (1992) were used to test the Engle-Granger hypothesis, H_0: The series are not cointegrated against Ha: The series are cointegrated. If the cash and futures price series were found to be cointegrated the series were modeled using an ECM-GARCH model (Yang and Awokuse, 2003), however if they were not cointegrated a BEKK-GARCH model was used. Results are presented in Table 4.

Table 4. Engle-Granger test for cointegration

		Wheat - No. 2 Soft Red (CME)		Live Cattle (CME)	
		Dependent = log(C)	Dependent = log(F)	Dependent = log(C)	Dependent = log(F)
C	AIC	-2.34277	-2.15851	-5.07427*	-3.77964*
C	BIC	-2.34277	-2.15851	-5.81276*	-4.89026*
C	RDTN	-2.34277	-2.15851	-5.43014*	-3.77964*
C&T	AIC	-3.32615	-3.39299	-5.04518*	-3.84331*
C&T	BIC	-3.60820	-3.58156	-5.78989*	-4.94719*
C&T	RDTN	-3.32615	-3.39299	-5.39422*	-3.84331*

Significance at 0.05 denoted by **
C – Constant C&T – Constant and trend

Before moving on to the next stage in the empirical methodology, a second test, namely the Gregory-Hansen cointegration test was performed (Gregory & Hansen, 1996). This cointegration test has the same hypothesis as the Engle-Granger test, but differs by allowing for one unknown structural break. The gregoryhansen.src code was used to perform this test. Two Gregory-Hansen tests for cointegration were preformed for each commodity; the first allowed for a change in level, and the second allowed for a change in the level and trend. The Gregory-Hansen test for cointegration limits breakpoints to seventy percent of the data points, excluding fifteen percent from each the beginning and the end of the data series. This limited the ability of the Gregory-Hansen cointegration test to pick up all the structural breaks, especially since many of the structural breaks appear to occur near to the end of the data series (refer to price series graphs found in the data description section). Results are presented in Table 5.

Table 5. Gregory-Hansen test for cointegration

		Wheat - No. 2 Soft Red (CME)		Live Cattle (CME)	
		Dependent = log(C)	Dependent = log(F)	Dependent = log(C)	Dependent = log(F)
L	AIC	-3.50303	-4.51149	-5.25174*	-5.93519*
	BIC	-3.50303	-4.51149	-6.00739*	-5.15691*
	RDTN	-4.51149	-4.54682	-5.93519*	-5.04059*
L&T	AIC	-4.36970	-4.53898	-5.33644*	-5.93519*
	BIC	-4.53645	-4.56815	-6.10294*	-5.05793*
	RDTN	-4.51149	-4.54682	-5.93519*	-5.04059*

Significance at $\alpha = 0.05$denoted by **

L –Level L&T – Level and Trend

HEDGE RATIOS AND EFFECTIVENESS

Three methods have been selected to estimate the hedge ratio – naive, OLS and GARCH. The first method, the naive hedge ratio, does not require any estimation or calculations because one futures position is taken for each cash position. This hedge does not change over time and does not depend on the underlying past or present data. The other two methods selected to estimate the hedge ratio are two of many estimation methods used to calculate the minimum-variance hedge ratio (Coakley, Dollery, & Kellard, 2008):

$$Minimum\ Variance\ Hedge\ Ratio = \frac{Cov(\Delta c_t, \Delta f_t)}{Var(\Delta f_t)}$$

Note that c_t and f_t are the log of the cash and futures price making the terms Δc_t and Δf_t the cash and futures return.

The OLS method calculates the minimum-variance hedge ratio by estimating the following regression equation using ordinary least squares (Coakley, Dollery, & Kellard, 2008):

$$\Delta c_t = \beta_0 + \beta_1 \Delta f_t + \varepsilon_t$$

The estimated value of β_1 is the minimum variance hedge ratio. This method for calculating the hedge ratio is commonly used due to its simplicity but has several drawbacks, one being that the hedge ratio does not change over time. For this research the OLS hedge ratio is calculated in RATS specifying robust standard errors in the OLS estimation.

The GARCH(p,q) method developed by Bollerslev (1986) calculates the optimal hedge ratio by estimating the equations:

$$r_t = \mu + \varepsilon_t \qquad \varepsilon_t = z_t \sigma_t \qquad \varphi_t^2 = \omega + \sum_i^q \alpha_i \varepsilon_{t-i}^2 + \sum_j^p \beta_j \varphi_{t-j}^2$$

The GARCH method of calculating the hedge ratio is appealing because it incorporates the most up to date data (up to and including t-1) which is achieved by a continual revision of the hedge ratio as denoted by subscript t. One drawback of the GARCH method is the transactions costs associated with the continual revision of the position. There are many ways to estimate the GARCH(p,q) model. For this research the BEKK framework (Engle & Kroner, 1995) was used to estimate GARCH(1,1) models in order to guarantee a positive semi-definite covariance matrix (Coakley, Dollery, & Kellard, 2008). Where cointegration was present, the residuals from the error correction model were added to the mean of the GARCH(1,1) model. The G@RCH component of OxMetrics were used to estimate all GARCH models.

The selected measure of hedging effectiveness is the reduction in variance which follows Yang and Awokuse (2003). The reduction in variance compares the variance of the unhedged portfolio with the variance of the hedged portfolio. The hedged portfolio is defined as $\Delta c_t - \gamma \Delta f_t$ for the naive and OLS hedge ratios and as $\Delta c_t - \gamma_t \Delta f_t$ for the GARCH hedge ratio where γ_t denotes the hedge ratio at time t. The reduction in variance reduction is calculated as $\left(1 - \frac{Var_H}{Var_U}\right) \times 100$ which gives the percentage reduction in variance. This allows the variance reduction to be compared across commodities. A hedge was considered to be more efficient if it had a higher reduction in variance (in percent), with a maximum value of 100%.

EMPIRICAL RESULTS

The ADF, KPSS and one/two-break unit root tests revealed that the log(cash) and log(futures) price series for each of the eight data series were first-difference stationary after accounting for structural breaks. Fractional integration did not appear to exist for two reasons: first, the unit root and stationarity tests agreed in all cases for four of eight commodities at a 0.05 significance level and five of eight commodities at a 0.025 significance level and second, the conclusion for log(cash/futures) and Δlog (cash/futures) conflicted in all cases for the one/two-break unit root test. The same conclusion has been made in previous time periods for wheat (Yang, Bessler, and Leatham, 2001) (Covey & Bessler, 1995), corn (Yang, Bessler, and Leatham, 2001) (Zapata & Fortenbery, 1996), feed cattle (Yang, Bessler, and Leatham, 2001), live cattle (Yang, Bessler, and Leatham, 2001) (Covey & Bessler, 1995), and lean hogs (Yang, Bessler, and Leatham, 2001).

Both the Engle-Granger and the Gregory-Hansen tests for cointegration revealed that the log(cash) and log(futures) price series were cointegrated for all commodities except wheat. For each commodity the results were the same no matter if log(cash) or log(futures) was the dependent variable. Feeder cattle was the only commodity that did not reach a unanimous conclusion across all six variations of the Engle-Granger test (i.e., AIC/BIC/Reduction; constant/constant and trend). Although the cointegration test for feeder cattle did not reach a unanimous conclusion, only two of the six tests indicated that the series were not cointegrated giving a strong indication that the log(cash) and log(futures) price series were cointegrated. The results of the Gregory-Hansen tests for cointegration allowing for one structural break concurred in all cases, strengthening the conclusions.

Findings from previous literature on cointegration between cash and futures prices indicate that there is no clear consensus on whether or not commodity prices are cointegrated. This can be seen in the fact that the same conclusion has been made in previous time periods for wheat (Yang, Bessler, and Leatham, 2001), corn (Yang, Bessler, and Leatham, 2001) (Zapata & Fortenbery, 1996), feeder cattle (Yang, Bessler, and Leatham, 2001), live cattle (Yang, Bessler, and Leatham, 2001), and lean hogs (Yang, Bessler, and Leatham, 2001) while a conflicting conclusion has been made in previous time periods for wheat (Covey & Bessler, 1995), feeder cattle (Covey & Bessler, 1995), live cattle (Bessler & Covey, 1991), lean hogs (Schroeder & Goodwin, 1991).

The OLS hedge ratios calculated as described in the previous section are found in Table 6. The hedge ratio ranged from 0.109 for lean hogs to 1.032 for wheat. The naive hedge ratio would have performed similar to the OLS hedge ratio for gold, wheat, corn, and soybean meal because the OLS hedge ratio is close to one; however, the naive hedge ratio but would have performed relatively poorly for feeder cattle, live cattle and lean hogs. This indicates that caution must be taken when using the naive hedge ratio.

Table 6. OLS hedge ratio

OLS Hedge Ratio	Gold	Silver	Wheat	Corn
	0.9183884872	0.6915714538	1.03234	0.9171119892
	Soybean Meal	Feeder Cattle	Live Cattle	Lean Hogs
	0.904614334	0.189153934	0.169137009	0.1086568582

Since one statistic cannot describe the time-varying GARCH hedge ratio graphics have been provided for each commodity in Figure 9. The ECM-GARCH method has been used to estimate the GARCH hedge ratio for gold, silver, and soybean meal. The BEKK-GARCH method has been used to estimate the GARCH hedge ratio for wheat, feeder cattle, live cattle, and lean hogs. The ECM-GARCH method was not used for wheat because the price series are not cointegrated. On the other hand, the price series for feeder cattle, live cattle and lean hogs are cointegrated. The GARCH hedge ratio was originally estimated using the ECM-GARCH method for these three commodities resulting in non-convergence. Several variations of the ECM-GARCH method were estimated, each resulting in non-convergence. The decision was made to estimate the BEKK-GARCH model, which resulted in convergence. The BEKK-GARCH model was reduced to the ARCH model for lean hogs and live cattle because the GARCH term was not significantly different from zero.

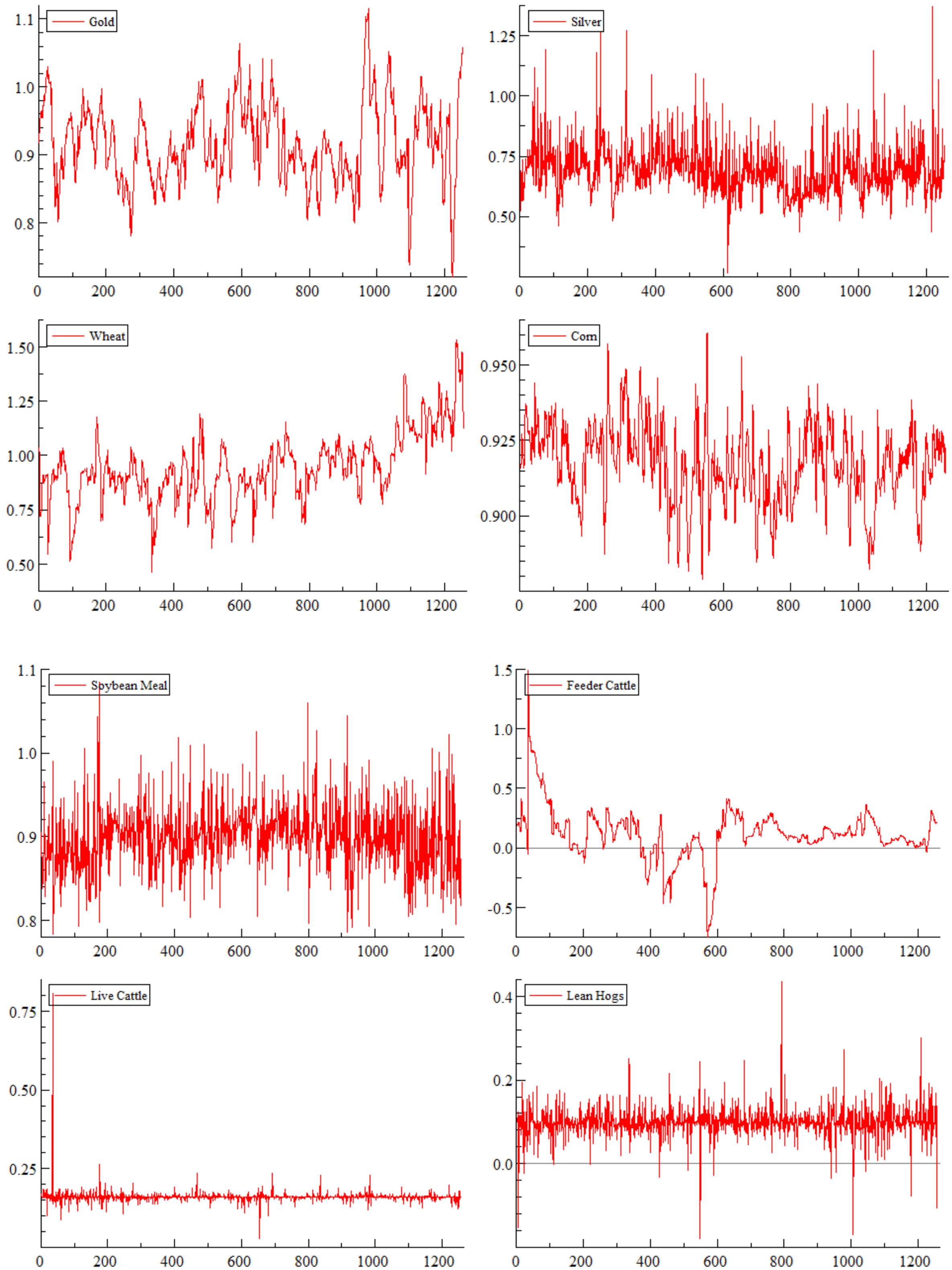


Figure 9. GARCH Hedge Ratios for the Eight Commodities (06/11/2003-05/11/2008)

The hedging effectiveness for the three hedge ratios are found in Table 8. The effectiveness of the naive hedge ratio was similar to the OLS and GARCH for all commodities except feeder cattle, live cattle and lean hogs. In all three cases, the naive hedge ratio increased rather than decreased the variance of the portfolio. The OLS hedge ratio outperformed the GARCH hedge ratio for silver, soybean meal, feeder cattle, live cattle, and lean hogs. The GARCH hedge ratio only outperformed the OLS hedge ratio for silver. Equal performance was observed for the two remaining commodities, corn and wheat. Overall, the maximum difference between the performance of the OLS and GARCH hedge ratio was 4.05%.

Table 8. Naive, OLS and GARCH portfolio variance reduction (in comparison to no hedge)

	Gold¤	Silver¤	Wheat*	Corn¤	Soybean Meal¤	Feeder Cattle*	Live Cattle**	Lean Hogs**
Naive (1:1)	80.00%	41.18%	64.99%	75.00%	69.87%	-25.09%	-46.19%	-104.99%
OLS	81.07%	51.52%	65.12%	75.50%	70.71%	1.47%	2.03%	1.55%
GARCH	81.07%	49.90%	65.89%	75.50%	70.50%	-2.58%	1.52%	0.93%

¤ECM-GARCH *BEKK-GARCH **ARCH

The reduction in portfolio variance (in comparison to no hedging) found by Yang and Awokuse (2003) for the time period between January of 1997 and December of 2001 are presented alongside the findings of this chapter[1] in Table 9 for the five commodities studied by Yang and Awokuse (2003). It is interesting to note that the effectiveness of the hedging mechanism provided by the commodity futures markets for wheat and live cattle are very similar while the effectiveness for corn and live cattle differ by almost 25 percent, and the effectiveness for lean hogs differs by 50 percent. Had the five commodities in the table below been classified as they were by Yang and Awokuse (i.e., wheat and corn are storable commodities while feeder cattle, live cattle and lean hogs are non-storable commodities), the evidence from the recent data set would provide additional evidence in favour of their conclusion, "the evidence shows that the hedging effectiveness is strong for all storable commodities but weak for all non-storable commodities under consideration" (2003).

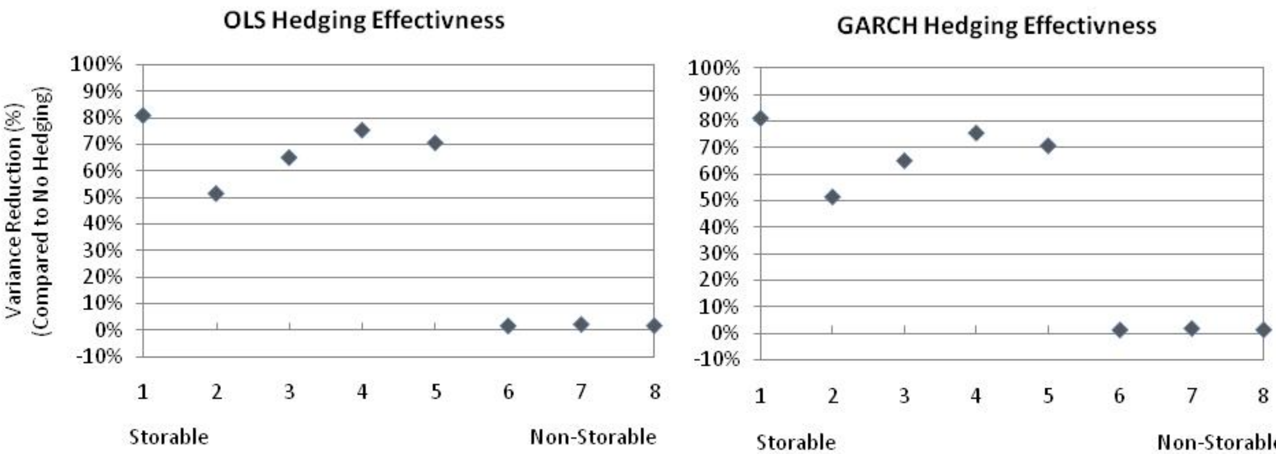
Table 9. Portfolio Variance Reduction using GARCH hedge ratio (in comparison to no hedge)

	Wheat	Corn	Feeder Cattle	Live Cattle	Lean Hogs
01/01/1997-31/12/2001 (Yang and Awokuse, 2003)	66%	51%	21%	0%	52%
06/11/2003-05/11/2008	65.89%	75.5%	-2.58%	1.52%	0.93%

This result is not as clear when taking into consideration the three additional commodities incorporated in this chapter. If the futures market of a non-storable commodity performs poorly in its hedging function compared to the futures market of a storable commodity one would expect to see a negative trend when plotting portfolio variance reduction as a function of storability. This plot is found in Figure 10. Keep in mind that the storability measure in this case is ordinal not continuous thus one should not expect to see a linear, quadratic or other smooth function.

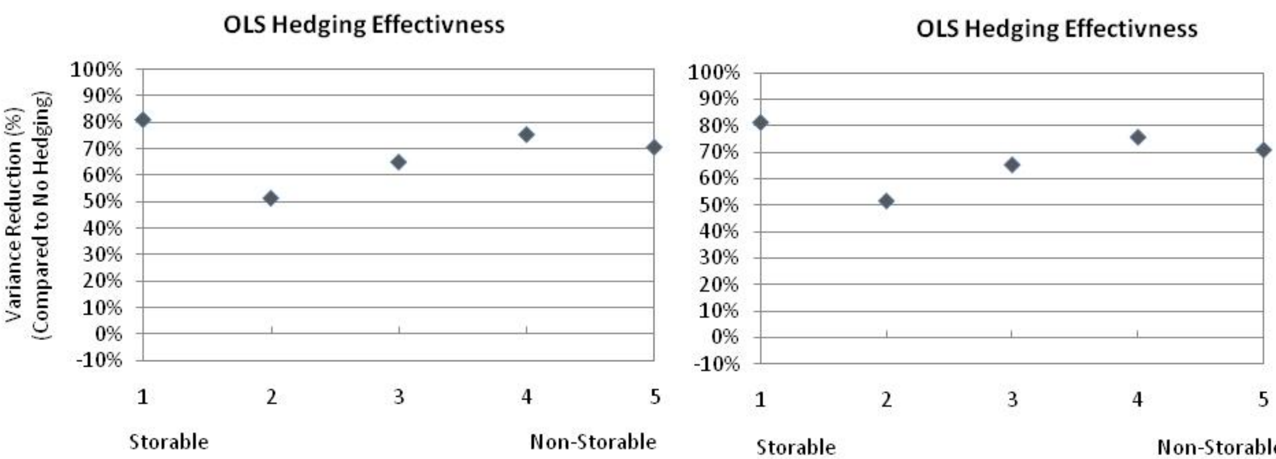
[1] A direct comparison was not made with Choudhry (2009) because the within sample portfolio spanned 24 years.

Figure 10. Portfolio Variance Reduction as a Function of Storability



Upon ocular inspection of Figure 10 it is clear that the less storable commodities ranked number six, seven and eight performed much poorer in their hedging function in comparison to the more-storable commodities one through five. However, when commodities six, seven, and eight (i.e., livestock futures contracts) are removed from the plot the trend no longer exists (see Figure 11).

Figure 11. Portfolio Variance Reduction as a Function of Storability



Overall, the results found in this research agree with Choudhry (2009). The empirical results do not show a significant difference in the hedging effectiveness of storable and non-storable commodities. On the other hand, there is clear evidence that the futures market for livestock performs poorly in its hedging function compared to the futures market for other commodities, which is an interesting area for future research.

CONCLUSION

The findings of this research lead to several important implications for users of the futures market for operational hedging. First, producers or procurers of non-storable commodities should not shy away from hedging with the futures market due to the fact that a commodity is non-storable. However, producers of procurers of livestock, specifically live cattle, feeder cattle and lean hogs should be wary of using the futures market for operational hedging and should consider other methods to reduce price risk such as forward contracts. Second, users of the futures market for operational hedging should be wary of using the naive (1:1) hedge ratio. This is especially the case for livestock producers, for which the naive hedge ratio increased price risk by 25 to 105 percent (as measured by variance reduction). Lastly, findings show that the OLS hedge ratio performed at least as well or better than the GARCH hedge ratio for seven of the eight commodities included in this study. This is good news to the users of futures markets for operational hedging because it means that they can reduce transaction costs by using the OLS hedge ratio without sacrificing portfolio variance reduction. The decreased transaction costs come from the constant hedge ratio as opposed to the time-varying hedge ratio determined by the GARCH method which may require frequent adjustments to the hedge ratio.

There are several areas that this research can be expanded upon in the future. The first area is to include more commodities, specifically commodities whose storability falls between live cattle and soybean meal. These commodities are difficult to find. However, if the frequency of the data were reduced from daily to weekly, concentrated orange juice and milk could be added into the suite of commodities. These commodities could help separate the effects of storability and the livestock industry. The second area of expansion is to include data up until the present date. This would allow more accuracy when determining structural breaks since the structural break occurred near to the end of the data series used for this research. A third area for future research is to investigate the livestock industry and find a better method of determining the optimal hedge ratio. It may be useful to test for fractional integration as well as fractional cointegration. The empirical tests performed indicate that the price series were I(1) however, the values were not very different from the critical values at a 0.05 level of significance.

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