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Abstract

This paper examines risk minimization hedging effectiveness for major storable and nonstorable agricultural commodity futures markets. Based on the error correction model – bivariate GARCH frameworks, some evidence is found that the hedging effectiveness is stronger for storable commodities than nonstorable commodities under consideration. The finding illustrates an important difference between storable and nonstorable commodities with regard to their hedging function.

Key words: Commodity futures, asset storability, hedging effectiveness, multivariate GARCH

JEL classification: D82, G19

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Introduction

Two major economic functions of commodity futures markets are to provide a hedging (or risk transfer) mechanism and to contribute to the process of price discovery. To have economic merit, commodity futures markets must offer either one or both of these functions. Thus, the knowledge of how effective hedging function performs on commodity futures markets is essential to our understanding of these markets. Further, some authors have argued that the commodity futures markets with different storability characteristics may perform in different manners (e.g., Skadberg and Futrell, 1966; Peck, 1976, 1985; Purcell and Hudson, 1985). Unfortunately, little serious empirical work has been done to test the validity of this argument. Particularly, for livestock futures markets, their underlying assets typically are nonstorable commodities. Compared to the case of storable commodities, the hedging function has been emphasized much more than the price discovery function in these markets (Purcell and Hudson, 1985). Surprisingly, effectiveness of the hedging function on these futures markets is still quite unclear (Skadberg and Futrell, 1966; Purcell and Hudson, 1985). Thus, an important but long overdue question should be formally investigated: does the futures market for a nonstorable commodity (e.g., livestock) perform poorly in its hedging function compared to the futures market for a storable commodity? Some researchers (Skadberg and Futrell, 1966; Peck, 1976, 1985; Purcell and Hudson, 1985) have presented related theoretical considerations supportive of such a suspicion. Many practitioners also did not use the livestock futures markets for hedging simply because they suspect the usefulness of the markets for that purpose (Purcell and Hudson, 1985, p. 331-332). However, the widespread suspicion has not yet been subject to empirical verification.

This study seeks to provide an answer to the important question above. The difference in the risk minimization hedging effectiveness between nonstorable and storable commodity futures markets will be estimated and contrasted. Related to this study, Covey and Bessler (1995) and Yang, Bessler, and Leatham (2001) examined the issue of the perceived sharp difference between storable and nonstorable commodity futures markets in the price discovery function. By contrast, whether some difference might exist in the other function of futures markets (i.e., hedging function) is an issue yet to be addressed. The main contribution of this study to the literature lies in that it is the first attempt to show (at least part of) the difference in hedging functioning between nonstorable and storable commodities. The organization of paper is as follows. Section II presents GARCH models. Section III describes the data and their time series property. Section IV presents empirical results from the analysis and finally, Section V contains the concluding remarks.

Methodology

The time-varying pattern of commodity price volatility is well documented in the literature (Yang and Brorsen, 1992, 1993). The GARCH effects of cash and futures prices are first examined in a univariate AR (*k*)-GARCH (*p*, *q*) model as specified below:

$$y_t = \mu + \sum_{s=1}^{s=k} a_s y_{t-s} + \varepsilon_t \tag{1a}$$

$$\varepsilon_t \mid \Omega_t \sim td(0, \sigma_t^2, v) \tag{1b}$$

$$\sigma_t^2 = \omega + \sum_{i}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j}^{q} \beta_j \sigma_{t-j}^2 \tag{1c}$$

where y_t is the return or the first difference of log price, *k* is the lag length, $td(0, \sigma_t^2, v)$ represents the student's *t* density function with mean zero, variance σ_t^2, and degree of freedom v, and *p* and *q* are lag lengths for the squared residuals and the conditional variance, respectively. Commodity price volatility is measured by the conditional variance σ_t^2 in the equation (1c), which is specified as a linear function of past squared errors, past values of the conditional variance.

Cash and futures prices for each commodity then are jointly modeled in an ECM-MGARCH model. Specifically, the data generating process is modeled as follows:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + \varepsilon_t (t = 2,...,T) \tag{2a}$$

$$\varepsilon_t \mid \Omega_{t-1} \sim D(0, H_t) \tag{2b}$$

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B \tag{2c}$$

where $X_t = \begin{pmatrix} CP \\ FP \end{pmatrix}$ in this study, *CP* stands for cash prices and *FP* nearby futures prices, $\varepsilon_t = [\varepsilon_1, \varepsilon_2]$, Ω_{t-1} is the conditioning information set at time *t*-1, C is an upper triangular matrix, $H_t = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix}$ is the conditional covariance matrix at time *t*.

There exist numerous parameterizations of the conditional covariance matrix H_t in multivariate GARCH models (Engle and Kroner, 1995). A popular specification is the diagonal specification which can be specified as follows:

$$vech(H_t) = C + A\ vech(\varepsilon_{t-1}\varepsilon'_{t-1}) + B\ vech(H_{t-1})$$

where *vech* is a vector stacking operator, *C* is a symmetric matrix, and A and B are diagonal matrices. Baillie and Myers (1991) and Myers (1991) have used the diagonal bivariate GARCH(1,1) to model cash and futures prices on the US agricultural commodity markets. This specification is appealing because it is parsimonious and its assumption that variances and covariance depends solely on past own history seems also intuitively plausible. However, the above diagonal representation has a severe drawback because the covariance matrix cannot be guaranteed to be positive definite. But we require that H_t be positive definite for any sensible parameterization (Engle and Kroner, 1995).

Different from previous studies, the MGARCH model specification in this study is based on the BEKK specification in Engle and Kroner (1995), which is sufficiently general and guarantees a positive definite conditional covariance matrix. Equations 2(a) – 2(c) are estimated simultaneously by using maximum likelihood estimation procedure. Many researchers have recently used the Multivariate Generalized Autoregressive Conditional Heteroscedasticity (MGARCH) to estimate time-varying hedge ratios on commodity markets, including Baillie and Myers (1991), Myers (1991), Steven (1992), Bera, Garcia and Roh (1997), Haigh and Holt (2000), among others. However, all commodities being considered in these studies are storable commodities and their focus is on estimation of the hedge ratio rather than hedging effectiveness. Though the hedge ratio and hedging effectiveness may be related to each other statistically in the multivariate GARCH model, they are conceptually different. Hence, the issue of different hedging effectiveness for nonstorable versus storable commodities has not yet been investigated.

Two measures are used in this study to gauge the hedging effectiveness of commodity futures markets. One measure is the time-varying conditional correlation, which can be computed as $CC = h_{12} / (h_{11} h_{22})^{1/2}$ (Darbar and Deb, 1997; Fleming, Kirby and Ostdiek, 1998). Fleming, Kirby and Ostdiek (1998, p.113) argue that the cross-market conditional correlation of returns measures hedging benefits. Thus, if the conditional correlation between cash and futures markets for a nonstorable commodity is significantly lower than that for a storable commodity, it would suggest that the hedging effectiveness for a nonstorable commodity is poor relative to that for a storable commodity. The other measure is the variance reduction measure as used in Baillie and Myers (1991) and Kavussanos and Nomikos (2000). The variance reduction is calculated by comparing the variance of the hedged portfolios implied by the computed hedge ratios each trading day and the variance of the unhedged cash portfolios as follows:

$$VR = 1 - \frac{VAR(\Delta CP_t - \gamma^* \Delta FP_t)}{VAR(\Delta CP_t)} \tag{3}$$

where $\gamma^* = h_{12} / h_{22}$ are the computed hedge ratios. The larger the reduction in the variance of unhedged cash portfolio, the higher the degree of hedging effectiveness.

Data and Empirical Results

The data used in this study consist of daily cash and nearby futures prices for storable commodities corn, soybean and wheat traded on Chicago Board of Trade (CBT), cotton and sugar traded on Cotton, Sugar and Coffee Exchange (CSCE), and for nonstorable commodities lean hogs, live cattle and feeder cattle traded Chicago Mercantile Exchange (CME)[1]. The nearby futures price series were constructed as follows. First, we specified the nearby futures contract which is a contract with the nearest active trading delivery month to the day of trading. Prices for the nearby futures contract are used until the contract reaches the first day of the delivery month or its expiry date. Then, prices for the next nearby contract are used. All data were obtained from Datastream International. The sample period of five years is from 1/1/1997-12/31/2001. The sample period allows for the recent hog futures contract specification changes from live hog to lean hog in 1997 and covers the period of the more market-oriented US agricultural policy as represented by the FAIR Act (which became effective in April 1996).

The results (not reported here) based on standard unit root test procedures show that each cash and futures price series is nonstationary in levels, but stationary in its first difference. The results in Table 1 show that each of the cash and futures prices exhibits GARCH effects. The finding extends the literature (e.g., Yang and Brorsen, 1992, 1993) in that GARCH effects are documented for all major nonstorable agricultural commodities. As mentioned earlier, previous studies focused on exploring major storable agricultural commodities. To determine if the models were correctly specified, a variety of diagnostic tests were conducted on the standardized residuals from AR (*k*)-GARCH model estimation. Ljung-Box Q tests show whether there is autocorrelation in the standardized residuals. Ljung-Box Q^2 tests show whether there is autocorrelation in the squared standardized residuals. ARCH tests show whether there is unexplained ARCH effect in the standardized residuals. The results (not reported here) confirm that the models were quite well specified.

Thus, we estimated bivariate ECM-GARCH models for each pair of cash and futures prices. As reported in Yang, Bessler and Leatham (2001), cash and futures prices for most of these commodities are cointegrated with the vector (1, -1). The significance of error correction terms verifies the necessity of imposing the cointegration constraint. Based on the estimation results of ECM-GARCH models, the conditional correlation is calculated between the cash and nearby futures prices for these commodities. In Table 2 we report the mean statistics for the estimated conditional correlations. The major interest is to compare the sample conditional correlation between storable and nonstorable commodities. The mean conditional correlations are much higher for storable commodities than for nonstorable commodities. Such a difference between storable and nonstorable commodities is obviously substantial, even though we do not offer a formal test here. Table 2 also reports the average variance reduction for every commodity under study. Interestingly, the difference between storable and nonstorable commodities with regard to their hedging effectiveness is smaller, as suggested by the second measure of hedging effectiveness. The average variance reduction for five storable commodities is higher than that for two out of three nonstorable commodities (live cattle and feeder cattle). However, only live cattle futures offer little hedging effectiveness. Our finding of weak hedging performance for live cattle futures is consistent with the variance reduction result on beef reported in Baillie and Myers (1991).

Interestingly, the hedging effectiveness of hogs in terms of both measures is comparable to all storable commodities. Yang, Bessler and Leatham (2001) also observe that both the live and lean hog futures contracts apparently behaves more similar to storable commodities in their price discovery functioning than to live and feeder cattle markets. Skadberg and Futrell (1966) provide a possible explanation that the hog market involves certain regular storage patterns for some pork products, compared to little storage of beef in cattle markets.

In sum, we show some evidence that the risk minimization hedging effectiveness is stronger for storable relative to that for nonstorable commodity futures markets. Some caveats are in order to appropriately interpret the implications of our findings. One caveat is that this study limits itself to the risk minimization hedging effectiveness. Working (1962) pointed out that hedging might also be conducted with other purposes such as profit or return maximization. Thus, the hedging effectiveness conclusion in this study seems most applicable to a popular type of hedging, operational hedging. The success of operational hedging depends on the existence of a high correlation between changes in spot prices and changes in futures prices over short intervals - day to day and even within the day (Working, 1962). Another related point is that even if the hedging/risk transfer function performs poorly on nonstorable commodity futures markets, it still may not make development of these markets unjustified. These markets may perform well in price discovery function, which can justify their economic merits. Yang, Bessler, and Leatham (2001) provides evidence for rather good price discovery performance in these nonstorable markets. Black (1976, p.176) argued that the big benefit from the futures market should be from its price discovery function rather than hedging/risk transfer function.

Conclusions

This study examines risk minimization hedging effectiveness for major storable and nonstorable agricultural commodity futures markets. Based on the error correction model – bivariate GARCH frameworks, the evidence shows that the hedging effectiveness is strong for all storable commodities but weak for all nonstorable commodities under consideration. The finding illustrates the great difference between storable and nonstorable commodities with regard to their hedging functioning. The findings may also improve understanding of the relative roles of hedging and price discovery functions performed by (nonstorable) livestock futures markets, which is important to effective use of these futures markets.

The finding carries some implications for users of futures markets, particularly nonstorable commodity (cattle, hogs, etc.) producers. Many did not use the livestock futures markets for hedging because they suspect the usefulness of the markets for that purpose (Purcell and Hudson, p. 331-332). If the use of commodity futures markets cannot effectively protect these livestock producers from price risk (and thus the income risk), they should proceed further along the line of some existing risk management alternatives (e.g., forward contracting and long-term marketing agreements). The finding is supportive of such a suspicion for live cattle but not for hogs.

BIBLIOGRAPHY

Baille, R.T., & Myers, R.J. (1991). Bivariate GARCH Estimation of the Optimal Commodity Futures Hedge. *Journal of Applied Econometrics*, 6,109-24.

Bera, A., P. Garcia and J. Roh (1997). Estimation of Time-Varying Hedge Ratios for Corn and Soybeans: BGARCH and Random Coefficient Approaches. *Sanknya*: *The Indian Journal of Statistics (Series B)*, 59, 346-368.

Black, F. (1976). The Pricing of Commodity Contracts. *Journal of Financial Economics*, 3, 167-179.

Covey, T., & Bessler, D.A. (1995). Asset Storability and the Information Content of Intertemporal Prices. *Journal of Empirical Finance*, 2,103-15.

Darbar, S. M., and P. Deb. (1997). Co-movements in International Equity Markets. *Journal of Financial Research*, 20, 305-322.

Engle, R. F. (1982). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of U.K. Inflation. *Econometrica*, 50, 987-1008.

Engle, R.F., & Kroner, K.F. (1995). Multivariate Simultaneous Generalized ARCH. *Econometric Theory*, 11, 122-150.

Fleming, J., C. Kirby, & B. Ostdiek. (1998). Information and Volatility Linkages in the Stock, Bond and Money Markets. *Journal of Financial Economics*, 49, 111-137.

Haigh, M., & M. Holt. (2000). Hedging Multiple Price Uncertainty in International Grain Trade. *American Journal of Agricultural Economics*, 82, 881-96.

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica,* 59, 1551-80.

Kavussanos, M.G. & N.K. Nomikos (2000). Futures hedging when the structure of the underlying asset changes: The case of the BIFFEX contract. *Journal of Futures Markets*, 20, 775-801.

Myers, R.J. (1991). Estimating Time-Varying Optimal Hedge Ratios on Futures Markets. *Journal of Futures Markets*, 11, 39-53.

Peck, A.E. (1976). Futures markets, supply response and price stability. *Quarterly Journal of Economics*, 90, 407-423.

Peck, A.E. (1985). The Economic Role of Traditional Commodity Futures Markets. In *Futures Markets: Their Economic Roles*, A.E. Peck, ed., American Enterprise Institute for Public Policy Research, Washington.

Purcell, W.D., & Hudson, M.A. (1985). The Economic Roles and Implications of Trade in Livestock Futures. In *Futures Markets: Regulatory Issues*, A.E. Peck, ed., American Enterprise Institute for Public Policy Research, Washington.

Skadberg, J. M., & Futrell, G. A. (1966). An Economic Appraisal of futures Trading in Livestock. *Journal of Farm Economics*, 48, 1485-1489.

Sephton, Peter S. (1993). Optimal Hedge Ratios at the Winnipeg Commodity Exchange. *Canadian Journal of Economics*, 26, 175-93.

Yang, J., D. A. Bessler, and D. J. Leatham. (2001). Asset Storability and Price Discovery of Commodity Futures Markets. *Journal of Futures Markets*, 21, 279-300.

Yang, Seung-Ryong, and B. Wade Brorsen. (1992) “Nonlinear Dynamics of Daily Cash Prices” *American Journal of Agricultural Economics*, 74:706-715.

Yang, Seung-Ryong, and B. Wade Brorsen. (1993) “Nonlinear Dynamics of Daily Futures Prices: Conditional Heteroscedasticity or Chaos?” *Journal of Futures Markets*, 13:175-191.

Working, H. (1962): “New Concepts Concerning Futures Markets and Prices.” *American Economic Review*, 52, 432-459.

Table 1. Results of GARCH (1,1)-t Process for Cash and Futures Prices

Coefficient (t-ratio)	Corn	Soybeans	Wheat	Cotton	Sugar	Hogs	Live Cattle	Feeder Cattle
				Cash Prices				
α	0.08*	0.07*	0.04*	0.06*	0.03*	0.27*	0.28*	0.06*
	(3.93)	(4.12)	(2.97)	(3.41)	(3.45)	(4.15)	(6.35)	(3.15)
β	0.87*	0.90*	0.93*	0.88*	0.97*	0.44*	0.66*	0.91*
	(26.10)	(36.40)	(38.01)	(26.83)	(119.20)	(5.18)	(15.35)	(58.29)
				Futures Prices				
α	0.09*	0.06*	0.02	0.01*	0.02*	0.04*	0.02*	0.01*
	(3.38)	(3.57)	(0.89)	(2.24)	(3.33)	(3.31)	(2.80)	(2.90)
β	0.86*	0.89*	0.74*	0.92*	0.98*	0.96*	0.98*	0.99*
	(20.40)	(31.65)	(2.04)	(21.30)	(163.37)	(104.04)	(204.16)	(174.97)

Note: “*”denotes significance at the 5% level.

Table 2 Mean Statistics for Two Estimated Hedging Effectiveness Measures

Corn	Soybeans	Wheat	Cotton	Sugar	Hogs	Live Cattle	Feeder Cattle
Mean Statistics of Daily Time Varying Conditional Correlation							
0.81	0.88	0.80	0.77	0.76	0.74	0.15	0.15
Average Percentage Variance Reduction (Compared to No Hedging)							
51%	24%	66%	27%	26%	52%	0%	21%

Footnotes

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[1] Through personal communication with Professor Raymond M. Leuthold, we are assured that the lean hogs futures is considered a nonstorable commodity futures contract.

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