The Effects of Cash Settlement on the Cash-Futures Prices and Their Relationship: Evidence from the Feeder Cattle Contract*

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1. Introduction

Contract specification is one of the major factors determining the success or failure of a futures contract. Exchanges need to modify the contract specifications from time to time to meet changing business conditions. Since the advent of the stock index futures contracts in 1982, delivery specifications for commodity futures have been gradually scrutinized. One of the main issues is the costs and benefits of cash settlement as an alternative to physical delivery.

Cash settlement provides at least two benefits. First, it eliminates many problems associated with physical delivery. This is particularly important when the delivery cost is high, as in the case of livestock. With cash settlement, traditional market manipulations such as cornering and squeezing become less feasible and less effective. Second, it ensures the convergence between the spot and futures prices at maturity. The absence of convergence reduces the effectiveness of the contract as a hedge instrument.

Of course, the extent of the above benefits hinges upon the reliability of the cash settlement index. A desirable index must minimize the possibility of manipulations. Lien (1989c) and Cita and Lien (1992, 1997a, 1997b) applied various statistical methods to construct, select, and compare different cash settlement indices. Shah (1998) applied the bootstrap method proposed by Cita and Lien (1997a) to construct an index for the bank lending and borrowing rates in India. Berkowitz (1998) combined robust estimation and bootstrap methods to obtain an improved cash settlement index method under certain circumstances. Kahl, Hudson and Ward (1989), Leuthold (1992), and Kimle and Hayenga (1994) expressed concerns for the possibility of manipulation of the cash settlement indices of livestock in the presence of higher buyer-seller concentration and higher geographical concentration. Moreover, there is always a trade-off between the

To investigate the convergence issue, one may turn to the magnitude and the variability of the basis, defined as the difference between the spot and futures prices. In general, the price of a futures contract requiring physical delivery tends to reflect the minimum of the spot price among the deliverable grades and locations (Garbade and Silber, 1983b). The price of a cash-settled contract is a weighted average of various spot prices. When there is no change in the deliverable grades or locations, the basis will likely decline under cash settlement unless changes in the settlement scheme have strong impacts on the spot prices. This conclusion may, however, become invalid when the number of deliverable grades (or locations) increases.

Analytically, the effects of cash settlement on the basis variability are undetermined even if there is no change in the deliverable grades or locations, as demonstrated by Lien (1989a) and Kimle and Hayenga (1994). The weight specification in the index is the principal determinant of changes in the basis variability. Thus, an optimal cash settlement contract may be designed to minimize the basis variability and maximize the hedging effectiveness (Lien, 1989b). Kenyon, Bainbridge, and Ernst (1991) discussed the case of allowing for changes in the deliverables. As expected, an undetermined result was obtained. The effects of cash settlement on the basis variability,
therefore, can only be established through empirical analysis. The feeder cattle futures contract is a case that serves this research purpose well.

Beginning with the September 1986 contract, the feeder cattle futures contract traded in the Chicago Mercantile Exchange has eliminated physical delivery and replaced it with cash settlement. The seemingly successful outcome raised the issue of adopting cash settlement schemes in other livestock futures markets. Kahl, Hudson and Ward (1989) considered this possibility for the live cattle futures. Kimle and Hayenga (1994) examined the live hogs futures. Leuthold (1992) provided detailed discussions for a general livestock futures. Later, beginning with the February 1997 contract, the Chicago Mercantile Exchange replaced the live hogs futures contract with the lean hogs futures contract. The latter is cash settled and adopts a carcass-based pricing system in accordance with industry practices (Ditsch and Leuthold, 1996). Thus, both contracts incurred a change from physical delivery to cash settlement. In addition, a change in the pricing system occurred in the live hogs futures simultaneously at the switching point.¹

This paper investigates the effects of cash settlement on the basis behavior, and more generally, on the relationship between the cash and futures prices of the feeder cattle. A new method allowing for time-varying conditional variance and covariance is proposed. More specifically, a bivariate GARCH (Generalized Autoregressive Conditional Heteroscedasticity) model is adopted to describe the conditional variances and covariances of the cash and futures returns. In addition, a dummy variable is incorporated into the GARCH equations to measure the effects of cash settlement on the

¹ The live/lean hogs contract may be another interesting case study for the examination of the effects of cash settlement. Due to its short history in cash settlement, however, there are not enough observations to model the time-varying volatility structure of the live/lean hogs contract. While we manage to get some preliminary results for this contract, a detailed study on this contract will have to be postponed.
conditional mean, variance and covariance. The results show that the volatility in both cash and futures markets declined after physical delivery was replaced by cash settlement. In terms of futures hedging, cash settlement led to smaller but more stable hedge ratios. The residual risk (i.e., the risk of the hedged portfolio) also decreased drastically. Thus, we find that cash settlement was beneficial to the feeder cattle futures market.

The balance of this paper is organized as follows. In the next section, a literature review is provided. The drawbacks of previous approaches are discussed. The discussion leads to the proposed new statistical method in Section 3. In Section 4 the method is applied to the feeder cattle data. Some conclusions are given in Section 5.

2. Literature Review

Although many articles have discussed intuitively and analytically the costs and benefits of cash settlement versus physical delivery (for example, Jones, 1982; Garbade and Silber, 1983a; Paul, 1985; Lien, 1989a), the empirical literature is scanty. To date, only two futures contracts have actually switched from physical delivery to cash settlement, namely, the feeder cattle and live/lean hogs contracts. Moreover, as the change in the live/lean hogs contract is very recent, few studies are available.

Feeder Cattle futures contract is traded at the Chicago Mercantile Exchange. Before September 1986 the contract was settled by physical delivery. The delivery called for feeder cattle of medium frame and the lower 2/3 of large frame size and No. 1 muscle thickness and the top 1/3 of the No. 2 muscle thickness according to Official U.S. Standards for Grades of Feeder Cattle. Cash settlement was implemented beginning with
the September 1986 contract. Cattle-Fax calculated a weighted average price of 600-800 pound steers which grade 60%-80% choice at the slaughter weight. This price is used as the final settlement price.

As at any given time only one of the two settlement (cash or physical delivery) specifications prevails, earlier research constructed hypothetical cash-settled futures price data and compared them with the actual prices of the futures contracts based upon physical delivery. Using Arkansas auction prices as cash prices, Elam (1988) found that cash settlement generally led to a larger hedge ratio and reduced the hedging risk of feeder cattle. Schroeder and Mintert (1988) considered three different cash price series (Amarillo, Dodge City, and Kansas City) and obtained similar results in favor of cash settlement. However, it must be noted that both studies examined only the delivery periods when the hypothetical futures price data were deemed more reliable.

Rowsell and Purcell (1990) applied the actual futures price data from both pre- and post-switch to cash settlement to examine possible changes in the pattern of the basis and in the lead-lag relationship between the cash and futures prices. Cash prices were referred to the Oklahoma City feeder cattle. They found that the price discovery function of the futures market became less effective after cash settlement was adopted. Kenyon, Bainbridge, and Ernst (1991) adopted both Virginia and Oklahoma City cash price data and found that, in contrast to the predictions of Cohen and Graham (1985), cash settlement had no effect on the basis variance. In a comprehensive study, Rich and Leuthold (1993) considered price data from twenty-seven cash market terminals. They found that, following the introduction of the cash settlement, the maturity basis risk generally decreased and the mean of the basis increased significantly as the futures price
decreased relative to the cash price. More importantly, cash settlement reduced both the basis risk and the hedging risk at the industry level, with, however, mixed effects on the basis risk across different cash markets. Using daily closing prices of nearby futures, Schmitz (1997) found an improved correlation between the cash and futures prices but otherwise no other definite conclusions could be obtained. He expressed concerns for possible time-related changes in the basis variance and price correlation. To address these concerns, we adopt the GARCH models in this paper. We allow the conditional variance and covariance of the cash and futures returns to be time varying. This approach relaxes the restrictions of time-invariant variance and covariance in previous studies.

With the exception of Rowsell and Purcell (1990) and Rich and Leuthold (1993), all previous works used the variance and covariance to evaluate the effects of cash settlement. Rowsell and Purcell (1990) constructed a vector autoregression (VAR) model to investigate possible changes in the Granger causality between the cash and futures prices. Rich and Leuthold (1993) considered 27 cash markets. To examine the effects on hedge risk and basis risk, they added a dummy variable to represent the change from physical delivery to cash settlement in a linear regression model. While previous works assumed constant variance and covariance for both cash and futures prices, recent findings, however, indicate that both variance and covariance are more likely to be time varying. Thus, these results are subject to re-examination.

3. Methodology

The issue of time-varying variance and covariance is, of course, not unnoticed in the literature. In investigating the effects of derivative markets on stock returns, many
authors assumed that a constant stock return volatility prevailed before the introduction of the derivative with a one-time change in volatility after the introduction. The effect of the derivative is then measured by the change in the volatility. Jochum and Kodres (1998) provided a good discussion. Highlighting the importance of time-varying volatility, Gulen and Mayhew (1998), Hernandez-Trillo (1999), and Jochum and Kodres (1998) revisited the issue by introducing various versions of GARCH models. Li and Engle (1998) provided several competing GARCH models to characterize the “macroeconomic announcement effects”. All these works enlisted univariate GARCH models. In this study we explore the interaction between the cash and futures returns using bivariate GARCH models.

Let $S_t$ denote the logarithm of the cash price at time $t$ and $F_t$ denote the logarithm of the price of the nearby futures contract at time $t$. The nominal returns of the cash and futures markets are calculated as $R_{s,t} = S_t - S_{t-1}$ and $R_{f,t} = F_t - F_{t-1}$, respectively. We define the basis as the difference between the cash and futures prices (in logarithms) in percentage, thus, $B_t = (S_t - F_t) \times 100$. Due to the unit root and cointegration properties of the two time series (see the next section for the results), we examine the following error-correction model:

1. $\Delta R_{s,t} = \alpha_{s0} + \sum_{i=1}^{m} \alpha_{s1} \Delta R_{s,t-i} + \sum_{j=1}^{n} \beta_{sj} \Delta R_{f,t-j} + \gamma_s B_{t-1} + \epsilon_{s,t}$,

2. $\Delta R_{f,t} = \alpha_{f0} + \sum_{i=1}^{m'} \alpha_{f1} \Delta R_{f,t-i} + \sum_{j=1}^{n'} \beta_{fj} \Delta R_{s,t-j} + \gamma_f B_{t-1} + \epsilon_{f,t}$.

To capture the time-varying variance and covariance of the residual series $\epsilon_{s,t}$ and $\epsilon_{f,t}$, we consider bivariate GARCH models. Several versions of bivariate GARCH models may be used, such as the BEKK model (Engle and Kroner, 1995), the vech-diagonal
model (Bollerslev, Engle and Wooldridge, 1988) and the constant-correlation model (Bollerslev, 1990). Experience with empirical works shows that the BEKK and vech-diagonal models are prone to problems of nonconvergence (see Lien, Tse and Tsui, 1999, for example). While the constant-correlation model is relatively easy to estimate, the assumption of constant correlation may be too restrictive. Certainly this assumption has to be examined before inference based on the model can be relied upon. In this paper, we adopt the general bivariate GARCH model suggested by Tse and Tsui (1998). This model is relatively easy to estimate and yet can incorporate time-varying correlation. It has an advantage over the vech-diagonal form in that it is much easier to control the conditional variance-covariance matrix to be positive definite during the process of optimization. Yet the model is flexible enough to allow for time-varying correlations. Indeed, this model encompasses the constant-correlation GARCH model, so that the assumption of constant correlation can be tested under the general model.

Following Tse and Tsui (1998) we assume that the conditional variance of each time series is generated from a univariate GARCH process. For the conditional correlation coefficient, a similar structure is postulated. Specifically, the following equations are assumed.

\[
\begin{align*}
\sigma_{ss,t} &= \phi_{s0} + \sum_{i=1}^{p} \phi_{si} \sigma_{ss,t-i} + \sum_{j=1}^{q} \theta_{sj} \varepsilon_{s,t-j}^2, \\
\sigma_{ff,t} &= \phi_{f0} + \sum_{i=1}^{p'} \phi_{fi} \sigma_{ff,t-i} + \sum_{j=1}^{q'} \theta_{fj} \varepsilon_{f,t-j}^2, \\
\rho_s &= \rho (1-\delta_{1} - \delta_{2}) + \delta_{1} \rho_{t-1} + \delta_{2} \tau_{t-1},
\end{align*}
\]

\[\text{In this paper we consider the bivariate GARCH version of the time-varying correlation model. The model, however, can be extended to higher dimensions. See Tse and Tsui (1998) for the details.}\]
where $\sigma_{i,t}$ is the conditional variance of $e_{i,t}$, $i = s$ or $f$; $\rho_t$ is the conditional correlation coefficient between $e_{st}$ and $e_{ft}$. Equation (5) allows the conditional correlation coefficient to vary over time while restricting its value to lie between $-1$ and $1$. The parameters $\delta_1$ and $\delta_2$ are assumed to be nonnegative, with the additional constraint $\delta_1 + \delta_2 \leq 1$. Thus, $\rho_t$ is a weighted average of $\rho_t, \rho_{t-1}$ and $\tau_{t-1}$. Hence, if $\tau_{t-1}$ and $\rho_{t-1}$ are well-defined correlation coefficients, $\rho_t$ is also a well-defined correlation coefficient. It can be easily seen that $\tau_{t-1}$ is always between $-1$ and $1$. Thus, provided we start off equation (5) with $\rho_0$ between $-1$ and $1$, a sequence of well-defined correlation coefficients $\rho_t$ can be generated. Consequently, provided the conditional variances are positive, the conditional variance-covariance matrices will be positive definite. In this paper we take $M = 2$. The log-likelihood function of the model can be found in Tse and Tsui (1998).

To gauge the effects of cash settlement on the futures and cash returns, we augment an additive dummy variable into the system. The conditional-mean equations then become

\[
\Delta R_{s,t} = \alpha_{s0} + \sum_{j=1}^{m} \alpha_{s} \Delta R_{s,t-j} + \sum_{j=1}^{n} \beta_{sj} \Delta R_{f,t-j} + \gamma_s B_{t-1} + \lambda_s D_t + e_{s,t},
\]

\[
\Delta R_{f,t} = \alpha_{f0} + \sum_{i=1}^{m'} \alpha_{fi} \Delta R_{f,t-i} + \sum_{j=1}^{n'} \beta_{fj} \Delta R_{s,t-j} + \gamma_f B_{t-1} + \lambda_f D_t + e_{f,t},
\]

where $D_t$ equals zero when the nearby futures contract is cash settled, and one otherwise. The two coefficients, $\lambda_s$ and $\lambda_f$, determine the effects of cash settlement on the cash and
futures returns. A positive $\lambda_s$ (or $\lambda_f$) indicates that the conditional mean of the cash (or futures) return decreased after the cash settlement was adopted. Similarly, the augmented conditional-variance equations are given by

$\sigma_{ss,t} = \phi_{s0} + \sum_{i=1}^p \phi_{si} \sigma_{ss,t-i} + \sum_{j=1}^q \theta_{sj} e_{s,t-j}^2 + \psi_s D_t,$

$\sigma_{ff,t} = \phi_{f0} + \sum_{i=1}^{p'} \phi_{fi} \sigma_{ff,t-i} + \sum_{j=1}^{q'} \theta_{fj} e_{f,t-j}^2 + \psi_f D_t.$

A positive $\psi_s$ (or $\psi_f$) indicates that the conditional variance of the cash return (or futures return) decreased after cash settlement.

To compare with the results in the literature, we also consider the behavior of the basis. We adopt a univariate GARCH model as follows:

$B_t = a_0 + \sum_{i=1}^N a_i B_{t-i} + \epsilon_{b,t},$

$\sigma_{b,t}^2 = c_0 + \sum_{j=1}^p \sigma_{b,t-j}^2 + \sum_{k=1}^Q d_k \epsilon_{b,t-k}^2,$

where $\sigma_{b,t}^2$ is the conditional variance of $\epsilon_{b,t}$. Furthermore, the dummy variable $D_t$ is added into both the conditional-mean and -variance equations. The model is then re-estimated. The estimated coefficient for $D_t$ indicates the effect of cash settlement on the basis risk.

The estimation results of the bivariate GARCH model can be applied to construct the optimal hedged portfolio in terms of variance minimization. We can compare optimal hedge ratios and the hedging risk for pre- and post-cash settlement periods. The results throw light upon the effects of cash settlement on the hedging performance.
4. Empirical Results

Data for the cash prices and the prices of the futures contracts of feeder cattle were obtained from the Commodity Systems Inc. The feeder cattle data covers the period from September 1977 through December 1998. Cash prices are referred to the seven-day average of 600-800 pound cattle, compiled by the Chicago Mercantile Exchange. The futures contract months are January, March, April, May, August, September, October and November. A weekly continuous time series of futures prices were extracted using the near contract month with roll over at approximately three weeks before maturity when the volume of the next contract picked up. The trading of feeder cattle usually has good volume only on Monday and Tuesday. To obtain reliable price information and to alleviate the possible problem of days of the week seasonality we used weekly data and selected Tuesday closing prices (prices for the previous working day was used if Tuesday was a holiday) for both the cash and futures. Altogether there are 1110 weekly price observations. The feeder cattle contract switched to cash settlement in August 1986. Thus, we have 463 observations based on physical delivery, while the remaining observations are based on the system of cash settlement.

We first examine the price data for prevalence of unit root and nonstationarity. We apply the augmented Dickey-Fuller (ADF) test to the cash and futures prices (both in logarithms). With four lags, a constant term and a trend, the ADF test statistic for the cash price is –3.12, which fails to reject the unit root hypothesis at the 10% level. The ADF statistic for the futures price is –3.27, which fails to reject the unit root hypothesis at the 5% level. Upon taking the difference, the ADF statistics for the cash and futures
returns are, respectively, $-14.31$ and $-15.37$; both are significant at the 1% level. We, therefore, conclude that both cash and futures returns are stationary.

While cash and futures prices are nonstationary, their difference (i.e., the basis) is stationary with an ADF statistic of $-8.42$. Table 1 provides the summary statistics for the basis, and the cash and futures returns. On average, both cash and futures returns are positive. The cash return is skewed to the left with a large kurtosis. Consequently, the Jarque-Bera statistic easily rejects the null hypothesis of a normal distribution. In fact, none of the series can be accepted as normally distributed. It is well-known that nonnormality in the unconditional distribution may be caused by the GARCH effects.

Next we estimate an error-correction model for the conditional-mean equations of the cash and futures returns. The following model is selected based upon the Akaike Information Criterion (AIC):

\[
\begin{align*}
\Delta R_{s,t} &= 0.131 - 0.069 \Delta R_{s,t-1} + 0.293 \Delta R_{f,t-1} - 0.185 B_{t-1}, \\
& \quad (0.050) \quad (0.029) \quad (0.028) \quad (0.018) \\
\Delta R_{f,t} &= 0.040 + 0.064 \Delta R_{f,t-1}, \\
& \quad (0.630) \quad (0.030)
\end{align*}
\]

The numbers in the parentheses are standard errors. While the futures return responds only to its own history, the cash return reacts to the history of the cash and futures returns as well as to the lagged basis. Thus, the futures market leads the cash market. This conclusion is consistent with Ollerman, Brorsen and Farris (1989) who suggested that the futures market served as a center for price discovery for feeder cattle.

To investigate the effects of cash settlement, we introduced a dummy variable into the two equations. In both cases, we found the coefficient of the dummy variable to
be statistically insignificant. Thus, we conclude that cash settlement has no impacts on the conditional means of the cash and futures returns versus physical delivery.

We calculated the Box-Pierce $Q$-statistics for the residuals and the squared residuals. For both residual series, the $Q$-statistics are not statistically significant. For example, $Q(10) = 13.7$ and $11.8$, respectively, for the residuals from the cash and futures equations. On the other hand, the $Q$-statistics of the squared residuals display statistical significance. For example, $Q(10) = 225.5$ and $260.4$, respectively, for the squared residuals from the cash and futures equations. These results indicate that GARCH effects prevail in both cash and futures series.

The bivariate GARCH model described in equations (3) to (6) is fitted to the data. Following the literature, we consider GARCH $(1, 1)$ processes. That is, we choose $p = q = p' = q' = 1$. The estimation results are displayed in the first column of Table 2.

To test for the adequacy of the model in capturing conditional volatility we calculate the residual-based diagnostics. It should be pointed out that the usual Box-Pierce $Q$-statistic as used widely in many empirical applications is not an asymptotically valid diagnostic (see Ling and Li (1999) for the details). Here we adopt the residual-based diagnostics as suggested by Tse (1999b). These diagnostics are based on the ordinary least squares estimates of the regression of the squared standardized residuals on their lagged values. The asymptotic distributions of these estimates can be found in Tse (1999b), in which diagnostics with asymptotic $\chi^2$ distributions are suggested. Specifically, we consider three test statistics, namely $Q_{11}$, $Q_{22}$ and $Q_{12}$. $Q_{11}$ and $Q_{22}$ are based on the regression of the squared standardized residuals of the cash and futures equations, respectively, while $Q_{12}$ is based on the cross product of the standardized
residuals of the two equations. Following the suggestion of Tse (1999b) we include two lagged residual terms in the regression. Thus, $Q_{ij}$ $(i, j = 1, 2)$ are distributed asymptotically as $\chi^2$ with two degrees of freedom when there is no misspecification. The results of these diagnostics are given in Table 2. It can be seen that there is no evidence of misspecification, i.e. the conditional variance structure is adequately captured by the bivariate GARCH model.

From Table 2 we can see that all the ARCH terms ($\theta_{s1}$ and $\theta_{f1}$) and the GARCH terms ($\phi_{s1}$ and $\phi_{f1}$) are statistically significant at the 1% level. Both $\phi_{s1} + \theta_{s1}$ and $\phi_{f1} + \theta_{f1}$ are close to one, indicating strong persistence in conditional volatility. On the other hand, neither $\delta_1$ nor $\delta_2$ is statistically different from zero at any conventional level of significance. Therefore, there is no evidence that the correlation coefficient is time varying. Based upon this conclusion, we re-estimate a bivariate GARCH model with a constant correlation. The results are displayed in the second column of Table 2. The estimates between the two models are nearly identical. A Lagrange Multiplier (LM) test (Tse, 1999) is conducted to test for the constancy of the correlation coefficient. The calculated statistic, which is asymptotically distributed as a $\chi^2$ with one degree of freedom, is 1.16, indicating that the null hypothesis of a constant correlation cannot be rejected at any conventional significance level.

We next examine whether the time-varying conditional variance incurred a one-time shift in response to the change from physical delivery to cash settlement. The dummy variable $D_t$ is added to both conditional-variance equations. The last column of Table 2 displays the estimation results. Note that $\psi_s$ is positive and statistically significant at the 2% level while $\psi_f$ is positive and statistically significant at the 1% level.
Thus, cash settlement has significant effects on the price variability. The introduction of cash settlement reduced the conditional variance of the cash and futures returns by 0.4690 and 0.2577, respectively. Also, note that the persistence in volatility (i.e., $\phi_{s1} + \theta_{s1}$ and $\phi_{f1} + \theta_{f1}$) decreases after the dummy variable is incorporated. This agrees with many results in the literature that structural change, if ignored, induces spurious persistence.

The reduction in the return variability may affect the hedging performance of the feeder cattle futures. We construct a (dynamic) minimum-variance hedge strategy based on the estimation results. The minimum-variance hedge ratio is calculated as the ratio of the conditional covariance between the cash and futures returns to the conditional variance of the futures return. Figure 1 displays the minimum-variance hedge ratio for the complete sample. Some summary statistics about the hedge performance are provided in Table 3. The hedge ratios became smaller but more stable after cash settlement was adopted. The average hedge ratio dropped from 0.3905 to 0.2838 and the variance of the ratio also decreased from 0.0049 to 0.0027. That is, a hedger would assume a smaller futures position in the post-cash settlement period. The resulting return and risk of the hedged portfolio are also summarized in Table 3. Cash settlement drastically reduced the risk of the hedged portfolio (from 3.7591 to 0.7924). Figure 2 shows the returns of the hedged portfolios.

We fit a univariate GARCH model to the basis series. Based on the AIC, the conditional-mean equation is obtained as:

$$B_t = 0.1083 + 0.6506 B_{t-1} + 0.1408 B_{t-3}. $$

The dummy variable $D_t$ is found to be statistically insignificant in the conditional-mean equation. The Box-Pierce $Q$-statistics suggest that the residuals are not serially correlated.
Significant GARCH effect, however, is detected. We proceed to estimate a univariate GARCH(1, 1) model. The result is as follows:

\[
\sigma^2_{b,t} = 0.1034 + 0.8926 \sigma^2_{b,t-1} + 0.0852 \varepsilon^2_{b,t-1}.
\]

\[
(0.0561) \quad (0.0314) \quad (0.0226)
\]

Thus, both ARCH and GARCH terms are statistically significant at the 1% level. Similar to the cash and futures returns, the basis series also display strong persistence in volatility (see Figure 3). A dummy variable is then added to examine the effects of cash settlement. The following results are obtained:

\[
\sigma^2_{b,t} = 0.2769 + 0.8137 \sigma^2_{b,t-1} + 0.0849 \varepsilon^2_{b,t-1} + 0.3676 D_t.
\]

\[
(0.1005) \quad (0.0466) \quad (0.0216) \quad (0.1443)
\]

The residual-based statistic calculated from the ordinary least squares regression of the squared standardized residuals of the basis on two lagged terms is 0.39, showing that there is no evidence of model misspecification. It can be seen that the coefficient for \(D_t\) is statistically significant at the 1% level. Thus, we conclude that cash settlement reduced the variability of the basis. Table 4 provides some summary statistics for the basis. While the average basis is similar for the pre- and post-cash settlement periods, the variance decreased by nearly 75%, from 16.086 to 4.3919. Also note that the incorporation of the dummy variable reduces the volatility persistence.

5. Conclusions

This paper investigates the effects of cash settlement on the behavior of the cash and futures prices in the feeder cattle market. We find that conditional volatility prevails in the feeder cattle prices and basis. Bivariate GARCH models are applied to estimate the effects of cash settlement. The results show that the volatility in both cash and
futures markets decline after physical delivery was replaced by cash settlement. In terms of futures hedging, cash settlement led to smaller but more stable hedge ratios. The residual risk (i.e., the risk of the hedged portfolio) also decreased drastically. In general, cash settlement was beneficial to the feeder cattle futures market.
References


### Table 1. Summary Statistics of the Feeder Cattle Data

<table>
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<th>Statistics</th>
<th>Cash Returns</th>
<th>Futures Returns</th>
<th>Basis</th>
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<tr>
<td>Mean</td>
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<td>0.0431</td>
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<td>Median</td>
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<td>0.1059</td>
<td>0.4999</td>
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<td>Maximum</td>
<td>9.8846</td>
<td>9.3190</td>
<td>14.039</td>
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<tr>
<td>Minimum</td>
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<td>Jarque-Bera Statistic</td>
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<td>No. of Observations</td>
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<td>1109</td>
<td>1109</td>
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Table 2. Estimation Results of Bivariate GARCH Models

<table>
<thead>
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<th>Parameter</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \phi_{s0} )</td>
<td>0.0274 (0.0110)</td>
<td>0.0274 (0.0109)</td>
<td>0.1254 (0.0537)</td>
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<td>( \phi_{s1} )</td>
<td>0.8870 (0.0221)</td>
<td>0.8871 (0.0220)</td>
<td>0.7580 (0.0695)</td>
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<td>( \theta_{s1} )</td>
<td>0.1051 (0.0219)</td>
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<td>0.1189 (0.0257)</td>
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<tr>
<td>( \phi_{f0} )</td>
<td>0.0847 (0.0375)</td>
<td>0.0847 (0.0379)</td>
<td>0.1514 (0.0530)</td>
</tr>
<tr>
<td>( \phi_{f1} )</td>
<td>0.8678 (0.0268)</td>
<td>0.8680 (0.0268)</td>
<td>0.8220 (0.0337)</td>
</tr>
<tr>
<td>( \theta_{f1} )</td>
<td>0.1175 (0.0242)</td>
<td>0.1173 (0.0240)</td>
<td>0.1230 (0.0240)</td>
</tr>
<tr>
<td>( \rho )</td>
<td>0.4462 (0.0254)</td>
<td>0.4457 (0.0241)</td>
<td>0.4511 (0.0240)</td>
</tr>
<tr>
<td>( \delta_1 )</td>
<td>0.6696 (1.3212)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \delta_2 )</td>
<td>0.0022 (0.0264)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \psi_s )</td>
<td></td>
<td></td>
<td>0.4690 (0.2233)</td>
</tr>
<tr>
<td>( \psi_f )</td>
<td></td>
<td></td>
<td>0.2577 (0.0951)</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-2038.69</td>
<td>-2040.18</td>
<td>-2018.12</td>
</tr>
<tr>
<td>( Q_{11} )</td>
<td>2.59</td>
<td>1.74</td>
<td>3.36</td>
</tr>
<tr>
<td>( Q_{22} )</td>
<td>0.08</td>
<td>1.41</td>
<td>3.92</td>
</tr>
<tr>
<td>( Q_{12} )</td>
<td>0.66</td>
<td>0.96</td>
<td>1.23</td>
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</tbody>
</table>

Notes: Model 1 is defined by equations (3) to (6), which allows for time-varying correlation coefficients. Models 2 and 3 assume a constant correlation coefficient. In addition, Model 3 incorporates a dummy variable each for the conditional-variance equations. \( Q_{11} \) and \( Q_{22} \) are the residual-based diagnostics for the bivariate GARCH models based on the squared standardized residuals of the cash and futures returns, respectively. \( Q_{12} \) is based on the cross product of the standardized residuals of the cash and futures returns. The \( Q \) statistics are asymptotically distributed as \( \chi^2 \) with two degrees of freedom when the models are adequately specified. Figures in parentheses are standard errors.
Table 3. Summary Statistics of Hedge Performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample Period</th>
<th>Mean</th>
<th>Variance</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedge Ratio</td>
<td>Complete</td>
<td>0.3282</td>
<td>0.0064</td>
<td>0.1458</td>
<td>0.6657</td>
</tr>
<tr>
<td></td>
<td>Physical Delivery</td>
<td>0.3905</td>
<td>0.0049</td>
<td>0.2190</td>
<td>0.6657</td>
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<td>Cash Settlement</td>
<td>0.2838</td>
<td>0.0027</td>
<td>0.1458</td>
<td>0.4958</td>
</tr>
<tr>
<td>Hedged Portfolio Returns</td>
<td>Complete</td>
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<td>2.0294</td>
<td>-10.492</td>
<td>7.6951</td>
</tr>
<tr>
<td></td>
<td>Physical Delivery</td>
<td>0.0943</td>
<td>3.7591</td>
<td>-10.492</td>
<td>7.6951</td>
</tr>
<tr>
<td></td>
<td>Cash Settlement</td>
<td>-0.0542</td>
<td>0.7024</td>
<td>-4.6803</td>
<td>3.8938</td>
</tr>
</tbody>
</table>
Table 4. Summary Statistics of the Basis

<table>
<thead>
<tr>
<th>Sample Period</th>
<th>Mean</th>
<th>Variance</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete</td>
<td>0.5177</td>
<td>9.2412</td>
<td>-12.482</td>
<td>14.039</td>
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<tr>
<td>Physical Delivery</td>
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<td>16.086</td>
<td>-12.482</td>
<td>14.039</td>
</tr>
<tr>
<td>Cash Settlement</td>
<td>0.5092</td>
<td>4.3919</td>
<td>-8.4893</td>
<td>5.9704</td>
</tr>
</tbody>
</table>
Figure 1: Minimum-Variance Hedge Ratio for Feeder Cattle
Figure 2: Return of Hedged Portfolios
Figure 3: The Basis