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Physical delivery versus cash settlement: an empirical study on the feeder cattle contract ☆

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Abstract

This paper investigates the effects of the switch from physical delivery to cash settlement on the behavior of the cash and futures prices of the feeder cattle contract traded on the Chicago Mercantile Exchange. A bivariate Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model is applied to estimate the conditional volatility structure, with a possible structural break due to the switch to cash settlement. The results show that the volatility of the futures prices (but not the cash prices) declined after physical delivery was replaced by cash settlement. In terms of futures hedging, cash settlement led to smaller and more stable hedge ratios. The variance of the hedged portfolio also decreased substantially. The evidence suggests that cash settlement is beneficial to the feeder cattle futures market.

JEL classification: G13

Keywords: Bivariate GARCH model; Cash settlement; Conditional heteroscedasticity; Feeder cattle; Minimum-variance hedge ratio; Physical delivery

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1. Introduction

Contract specification is a major factor determining the success 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 use of cash settlement as an alternative to physical delivery. Traditionally, futures contracts not previously offset are settled by actual delivery, in which the short delivers the physical product to the long in exchange for an amount of fund. On the other hand, in the cash settlement mechanism a contract is settled at the end of the last trading day by marking to the market, with the settlement price set equal to a specified cash market index.[1] It has been argued that cash settlement provides some benefits over physical delivery. First, it avoids the problem of high delivery costs as in the case of livestock. Second, market manipulations such as cornering and squeezing become less effective. Third, cash settlement ensures the convergence between the spot and futures prices at maturity.

Although many articles have examined analytically the costs and benefits of cash settlement versus physical delivery (see, for example, Jones, 1982; Garbade and Silber, 1983; Paul, 1985; Lien, 1989), the empirical literature is scanty. To date, only two futures contracts have switched from physical delivery to cash settlement, namely, the feeder cattle and the live/lean hogs contracts. Beginning with the September 1986 contract, the feeder cattle futures contract traded on the Chicago Mercantile Exchange has replaced physical delivery with cash settlement. The seemingly successful outcome raised the issue of adopting cash settlement in other livestock futures. Beginning with the February 1997 contract, the Chicago Mercantile Exchange replaced the live hogs futures contract with the lean hogs futures contract, which is cash settled.

Kenyon et al. (1991) and Rich and Leuthold (1993) studied empirically the effects of cash settlement on the feeder cattle contract. Dummy variables were used to represent the change from physical delivery to cash settlement, and the variance was assumed to be constant in each sub-period. Kenyon et al. found that cash settlement had no effects on the basis variance, while Rich and Leuthold showed that cash settlement reduced both basis risk and hedge risk. However, as the recent empirical finance literature shows that volatility is likely to be time varying, these results are subject to re-examination.

In this paper, we investigate the effects of the switch to cash settlement on the feeder cattle contract allowing for time-varying conditional variance. We use a bivariate Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model. A dummy variable is incorporated into the model to measure the effects of cash settlement on the conditional mean and variance. The results show that the volatility of the futures prices (but not the cash prices) declined after physical delivery was replaced by cash settlement. In terms of futures hedging, cash settlement led to smaller and more stable hedge ratios. The variance of the hedged portfolio decreased drastically. Thus, the feeder cattle futures contract became a more effective hedge instrument after the switch to cash settlement.

[1] See Cita and Lien (1997) for the methodology of the construction of cash market indices.

The balance of the paper is organized as follows. In Section 2, we describe the statistical methodology and the bivariate GARCH model. In Section 3, the empirical results are discussed. The analysis of the basis and the futures contract as a hedge instrument is given in Section 4. Section 5 concludes the paper.

2. Methodology

We explore the interaction between the cash and futures returns using a bivariate GARCH model. Let s_t and f_t denote the logarithm of the cash and (nearby) futures prices, respectively, at time t. The nominal returns of the cash and futures are calculated as $r_{st=}s_{t-1}$ and $r_{ft}=f_t-f_{t-1}$, respectively. We define the basis as $b_t=s_t-f_t$, which is the difference between the logarithmic cash and futures prices. Due to the unit root and cointegration properties of s_t and f_t (see the next section for the results), we examine an error-correction model. 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

$$r_{st} = \alpha_{s0} + \sum_{i=l}^{m} \alpha_{si} r_{s,t-i} + \sum_{j=1}^{n} \beta_{sj} r_{f,t-j} + \gamma_s b_{t-1} + \lambda_s D_t + \varepsilon_{st} \tag{1}$$

$$r_{ft} = \alpha_{f0} + \sum_{i=l}^{m'} \alpha_{fi} r_{f,t-i} + \sum_{j=1}^{n'} \beta_{fj} r_{f,t-j} + \gamma_f b_{t-1} + \lambda_f D_t + \varepsilon_{ft} \tag{2}$$

where D_t equals zero when the nearby futures contract is cash settled, and one otherwise. The two coefficients of D_t, λ_s and λ_f, determine the effects of cash settlement on the cash and futures returns, respectively.

To capture the time-varying variance and covariance of the residual $\varepsilon_t=(\varepsilon_{st},\ \varepsilon_{ft})'$, we consider a bivariate GARCH model. In particular, we adopt the constant-correlation model due to Bollerslev (1990). We let $\mathrm{Var}(\varepsilon_t|\Phi_{t-1})=\Omega_t$, where Φ_{t-1} is the information set at time $t-1$. We denote the diagonal elements of Ω_t (i.e., the conditional variances) by σ_{st}^2 and σ_{ft}^2, and the off-diagonal element by σ_{sft}. The conditional variances and covariance are assumed to be generated by the following equations[2]

$$\sigma_{st}^2 = \phi_{s0} + \phi_{s1}\sigma_{s,t-1}^2 + \theta_s \varepsilon_{s,t-1}^2 + \psi_s D_t \tag{3}$$

$$\sigma_{ft}^2 = \phi_{f0} + \phi_{f1}\sigma_{f,t-1}^2 + \theta_f \varepsilon_{f,t-1}^2 + \psi_f D_t \tag{4}$$

[2] We estimated the bivariate time-varying correlation GARCH model due to Tse and Tsui (in press) with the feeder cattle data, but found no support for time-varying correlation. A more general specification may include both lagged conditional variances in Eqs. (3) and (4). As shown in Section 3, however, the model specified in Eqs. (3)–(5) is adequate and passes the specification diagnostics.

$$\sigma_{sft} = \rho\sigma_{st}\sigma_{ft} \tag{5}$$

where ρ is the time-invariant correlation coefficient. The dummy variable D_t is added in Eqs. (3) and (4) to capture the effects of the settlement system. A positive Ψ_s (or Ψ_f) indicates that the conditional variance of the cash return (or futures return) decreased after the switch to cash settlement. We estimate the parameters of the conditional-mean and conditional-variance equations jointly using quasi-maximum likelihood (QML) method assuming normality. The standard errors are then computed form the robust QMLE variance matrix.

As cash settlement ensures the convergence between the spot and futures prices, it might be expected that cash settlement may reduce the basis variability. However, Lien (1989) showed that this result is analytically undetermined. To examine this issue empirically, we estimate a univariate GARCH model for b_t, augmented with the dummy variable D_t to capture the effect of cash settlement on the basis risk. The results are presented in Section 4.

3. The data and the estimation results

Data for the cash and futures prices of feeder cattle were obtained from the Commodity Systems The data cover the period from September 1977 through December 1998. The futures contract months are January, March, April, May, August, September, October and November. As 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 use weekly data and select Tuesday closing prices (prices for previous working day is used if Tuesday was a holiday). The futures prices are extracted using the near contract month with roll over at approximately 3 weeks before maturity. Altogether there are 1110 weekly price observations, with 463 observations based on physical delivery and 647 observations based on cash settlement. Fig. 1 presents the price series of the spot and futures, while Fig. 2 presents their nominal returns.[3] Fig. 2 shows that the volatility of the spot and futures is clustered.

We examine the price data for nonstationarity. The augmented Dickey–Fuller (ADF) test is applied to s_t and f_t. With four lags, a constant term and a trend, the ADF test statistics for the cash and futures prices are, respectively, −3.12 and −3.27. Thus, the unit root hypotheses for these series are not rejected at the 5% level. The ADF statistics for the cash and futures returns and the basis are, respectively, −14.31, −15.37 and −8.42,

[3] At the point of roll over, we have taken care to calculate the futures returns based on the contract of the same maturity month. This has ensured that there is no break in the return at the point of roll over. The dashed vertical line represents the time when the contract shifted to cash settlement. This applies to other graphs as well.

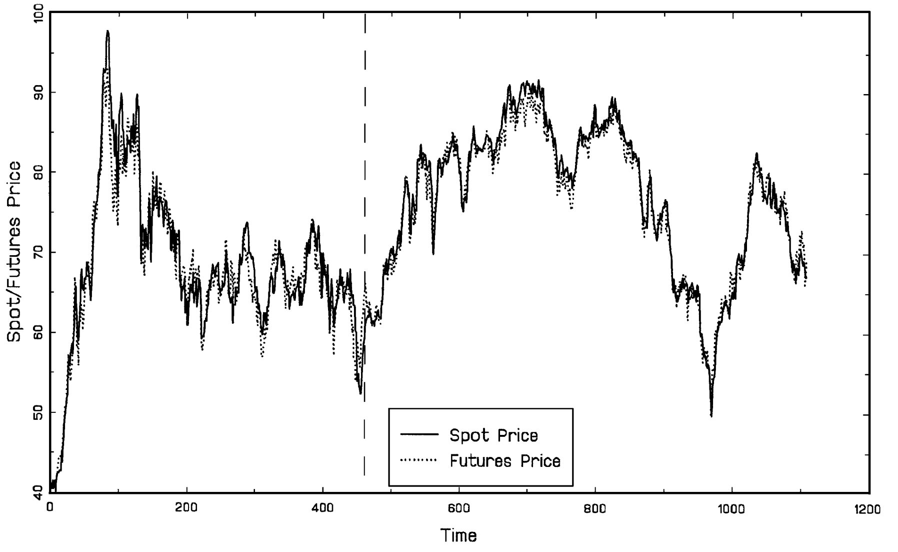

Fig. 1. Spot and futures prices of feeder cattle, 77/9–98/12.

suggesting that these series are stationary and the cash and futures prices are cointegrated. Panel A of Table 1 provides some summary for the basis, as well as the cash and futures returns.

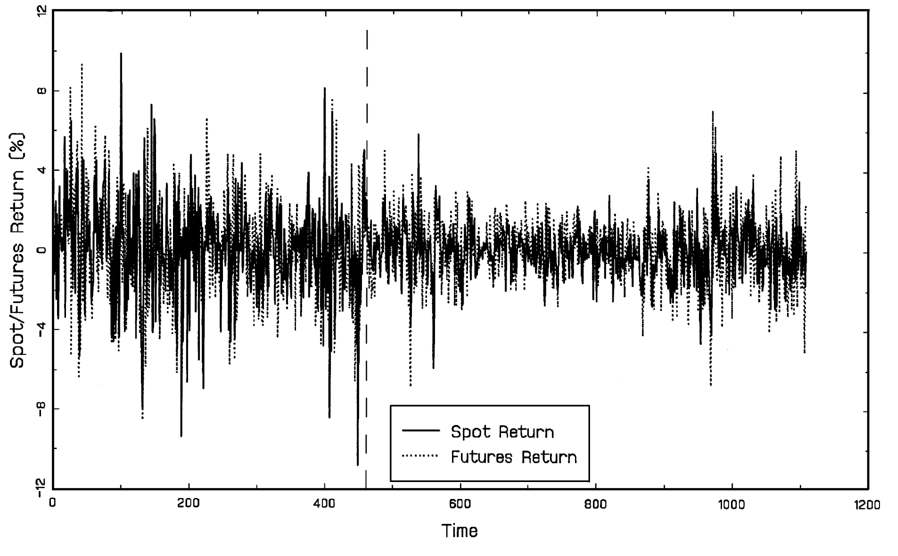

Fig. 2. Spot and futures returns of feeder cattle, 77/9–98/12.

We proceed to estimate an error-correction model with conditional volatility. The following model is obtained[4]

$$
\begin{aligned}
r_{st} &= \underset{(0.0371)}{0.1356} + \underset{(0.0239)}{0.3227}\, r_{f,t-1} - \underset{(0.0168)}{0.1970}\, b_{t-1} + \varepsilon_{st} \\
r_{f,t} &= \underset{(0.0490)}{0.1167} + \varepsilon_{ft} \\
\sigma_{st}^2 &= \underset{(0.0115)}{0.0191} + \underset{(0.0264)}{0.9012}\, \sigma_{s,t-1}^2 + \underset{(0.0263)}{0.0939}\, \varepsilon_{s,t-1}^2 \\
\sigma_{ft}^2 &= \underset{(0.0483)}{0.1252} + \underset{(0.0336)}{0.8316}\, \sigma_{f,t-1}^2 + \underset{(0.0261)}{0.1232}\, \varepsilon_{f,t-1}^2 + \underset{(0.1017)}{0.2334}\, D_t \\
\hat{\rho} &= \underset{(0.0256)}{0.4533} \\
\mathrm{LMC} &= 0.479 \quad Q_1(4) = 5.618 \\
Q_2(4) &= 1.133 \quad Q_{12}(4) = 3.232
\end{aligned} \tag{6}
$$

Several statistics are computed to test for model misspecification. LMC is the Lagrange multiplier statistic for the constant-correlation assumption suggested by Tse (2000). It is asymptotically distributed as χ_1^2 when the correlation coefficient is not time varying. We also compute the residual-based diagnostics by running the regression of the squared standardized residuals on their lagged values. Four lagged terms are considered. We account for the fact that the regressors are estimated using the results given in Tse (in press). The statistics are denoted by $Q_1(4)$ and $Q_2(4)$ for the spot and futures equations, respectively. Similarly, diagnostics based on the product of the standardized residuals of the spot and futures are calculated and denoted by $Q_{12}(4)$. When there is no model misspecification, the Q statistics are asymptotically distributed as χ_4^2. Based on the LMC and Q statistics, we conclude that there is no evidence of model misspecification.

Eq. (6) supports that there is no structural break (with respect to the switch to cash settlement) in the conditional-mean equation. The cash return responds to the lagged futures returns as well as to the lagged basis. In other words, the futures market leads the cash market. This result is in line with Ollerman et al. (1989), who argued that the futures market plays a role of price discovery. In the conditional-variance equation, D_t

[4] The numbers in parentheses are QMLE robust standard errors. The estimated model has been obtained after eliminating insignificant parameters from the general model.

Table 1
Summary statistics

Variable	Period	Mean	Maximum	Minimum	Variance	Skewness	Kurtosis	JB	$Q_1(10)$	$Q_2(10)$
Panel A										
Cash return	All	0.043	9.885	−10.767	3.590	−0.237	6.811	681.37	17.90	188.76
	PD	0.083	9.885	−10.767	6.289	−0.281	4.856	72.36	4.85	27.21
	CS	0.015	5.869	−5.839	1.667	0.004	4.956	103.12	18.57	92.08
Futures return	All	0.043	9.319	−8.534	4.388	0.020	4.562	112.78	14.95	269.27
	PD	−0.020	9.319	−8.534	6.827	0.102	3.598	7.70	15.75	51.30
	CS	0.088	7.063	−6.818	2.649	−0.098	4.423	55.66	13.12	74.42
Basis	All	0.520	14.039	−12.482	9.229	0.057	4.467	100.03	1951.26	1875.79
	PD	0.536	14.039	−12.482	16.027	0.152	3.126	2.090	920.14	630.08
	CS	0.509	5.970	−8.489	4.392	−0.501	4.046	56.522	587.73	133.90
Panel B										
Min-variance hedge ratio	All	0.331	0.656	0.153	0.0074					
	PD	0.383	0.656	0.203	0.0080					
	CS	0.295	0.511	0.153	0.0038					
Hedged portfolio return	All	0.041	8.436	−12.395	2.852					
	PD	0.103	8.436	−12.395	4.698					
	CS	−0.004	5.318	−5.428	1.542					

PD = physical delivery, CS = cash settlement, JB = Jarque-Bera statistic. Return and basis are measured in percentage. $Q_1(10)$ and $Q_2(10)$ are the Box–Pierce–Ljung statistics of the series and the squares of the series, respectively, based on lag order up to 10.

has significant effects for the futures return, but not the cash returns.[5] Thus, the switch to cash settlement reduced the conditional variance of the futures price but not the cash price.

4. Analysis of the basis and the effectiveness of hedging

From Panel A of Table 1, we can see that the average basis remains similar over the two settlement regimes. The variance of the basis in the cash-settlement period, however, dropped significantly. Fig. 3 plots the historical path of the basis. Again conditional volatility appears to exist. The estimated conditional-mean and conditional-variance equations of the basis are as follows

$$b_t = \underset{(0.0552)}{0.1471} + \underset{(0.0298)}{0.6048}\, b_{t-1} + \underset{(0.0269)}{0.1499}\, b_{t-3} + \varepsilon_{bt}$$

$$\sigma_{bt}^2 = \underset{(0.0954)}{0.2764} + \underset{(0.0422)}{0.8108}\, \sigma_{b,t-1}^2 + \underset{(0.0238)}{0.0870}\, \varepsilon_{b,t-1}^2 + \underset{(0.1498)}{0.3781}\, D_t \tag{7}$$

where ε_{bt} and σ_{bt}^2 are, respectively, the residual and the conditional variance of b_t. The coefficient of D_t is significant at the 1% level, suggesting that the conditional variance of the basis dropped due to the switch to cash settlement.

To examine the effect of cash settlement on hedging, we investigate the minimum-variance (MV) hedge strategy as studied by Baillie and Myers (1991). We consider a one-period hedge horizon. The time-varying MV hedge ratio (MVHR) is given by $h_t = \sigma_{sft}/\sigma_{ft}^2$. We apply the bivariate GARCH model estimated in the previous section to estimate h_t. Fig. 4 displays the MVHR for the complete sample. It can be seen that the MVHR became smaller and more stable after cash settlement was adopted. Summary statistics of the MVHR are presented in Panel B of Table 1. After physical delivery was replaced by cash settlement, the average hedge ratio dropped from 0.383 to 0.295 and the sample variance of the ratio decreased from 0.0080 to 0.0038. Thus, a hedger would assume a smaller futures position in the cash settlement period compared to the period of physical delivery.[6] Fig. 5 shows the hedged portfolio returns based on the MV hedge. We can see that cash settlement reduced the fluctuation in the returns of the hedged portfolio.[7] This is an

[5] The inference concerning the coefficient of D_t in the conditional-variance equation of the cash return was mixed. Using the Hessian or the cross product of the first derivatives to estimate the standard error, the coefficient was significant at the 5% level. However, when QMLE variance matrix was used, the coefficient was found to be insignificant. We note that the results in the next section concerning the effectiveness of futures hedge are not sensitive to whether the dummy variable is left out from the conditional-variance equation of the cash return.

[6] This result is in contrast to Elam (1988). Using Arkansas auction prices, Elam found that cash settlement generally led to larger hedge ratios. Elam's study, however, was based on a much shorter sample period.

[7] Note that the estimated conditional variances and covariances are based on the QMLE using the complete sample, so the MV hedge ratios are calculated within the sample. As such, the hedged portfolio returns are base on the data of the complete sample over the two settlement regimes. While out-of-sample comparison may be more interesting, there will be substantial loss in the estimation sample due to the segmentation of the data into two settlement regimes.

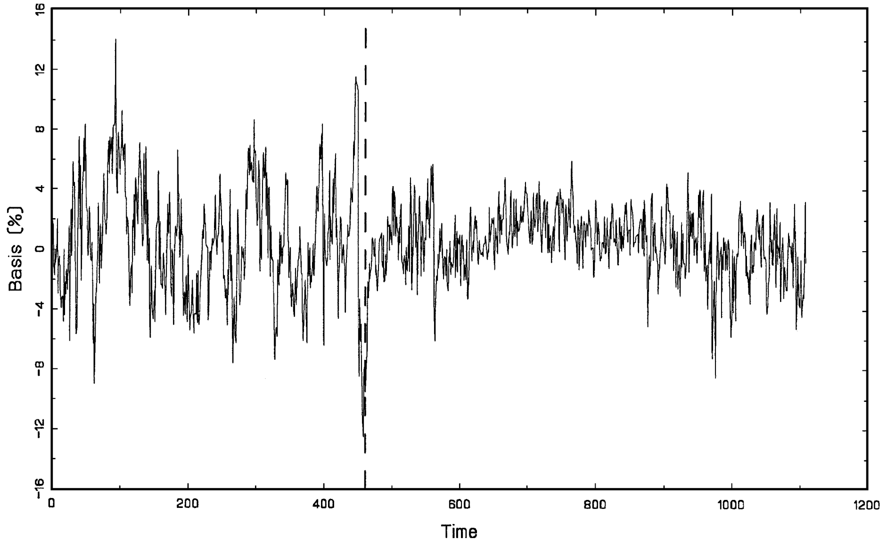

Fig. 3. The basis of feeder cattle, 77/9 – 98/12.

indication that the hedge performance became more effective after cash settlement. From Panel B of Table 1, we observe that the variance of the hedge portfolio return dropped from 4.698 to 1.542 due to the switch to cash settlement. Because of the low correlation

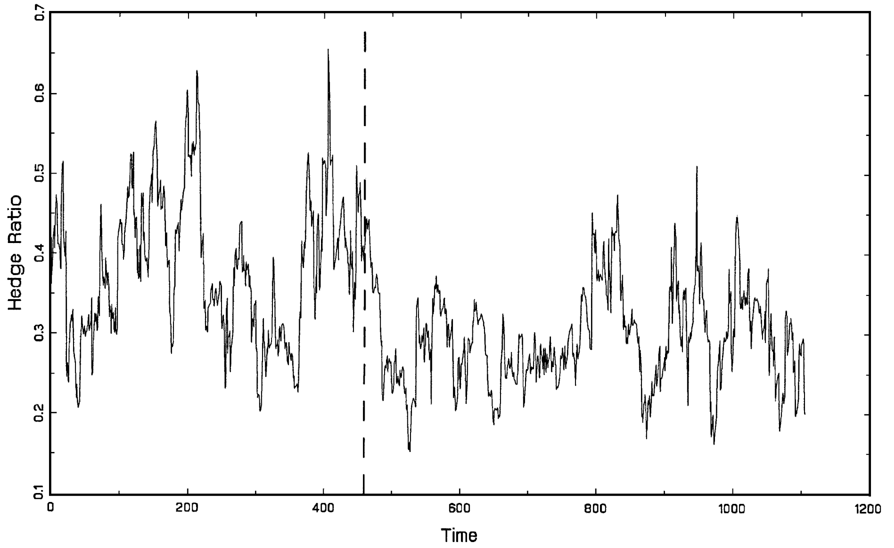

Fig. 4. Minimum-variance hedge ratio.

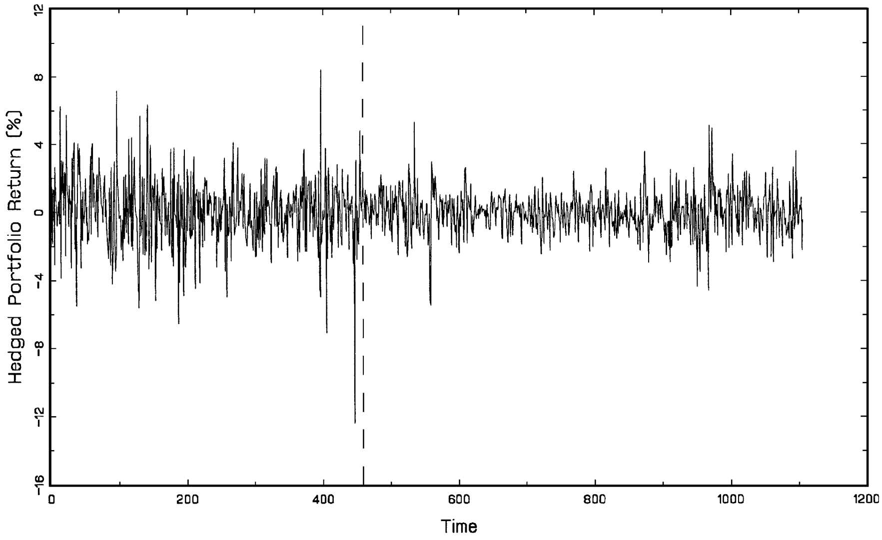

Fig. 5. Return of hedged portfolio.

between the cash and futures returns of 0.4533 (see Eq. (6)), however, the variance of the hedge portfolio still appears to be quite large.

5. Conclusion

Cash settlement was adopted by the Chicago Mercantile Exchange as a remedy to certain market problems such as unnecessarily high delivery rate, scheduling difficulties and dissatisfaction with delivered grades. In this paper, we investigate the effects of cash settlement on the behavior of the cash and futures prices in the feeder cattle market. Using a bivariate GARCH model to capture the time-varying volatility, we find that the volatility of the futures prices, but not cash prices, but not the cash prices, declined after physical delivery was replaced by cash settlement. In terms of futures hedging, cash settlement led to smaller and more stable hedge ratios. The residual risk, namely, the variance of the hedged portfolio, also decreased substantially. We conclude that cash settlement is beneficial to the feeder cattle futures market.

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