Hedge Effectiveness for Western Australia Crops

Zhibo Guo*, Ben White, and Amin Mugera
School of Agricultural and Resource Economics, the University of Western

Contributed paper prepared for presentation at the
57th AARES Annual Conference, Sydney,
New South Wales, 5th-8th February, 2013

Hedge Effectiveness for Western Australia Crops

Zhibo Guo*, Ben White, and Amin Mugera
School of Agricultural and Resource Economics, the University of Western Australia

Abstract

This paper reports a series of pre-trade investigations into the hedge effectiveness of futures contracts of wheat, barley, and canola for Western Australia hedgers. Hedge ratios were estimated through the ordinary least square model, the vector autoregressive model, and the vector error-correction model. Hedging effectiveness was measured using risk reduction method and utility maximization method. Results indicate that, despite being thinly traded contracts, futures on Australia Securities Exchange are more effective in wheat, barley, and canola in terms of price risks minimization and utility maximization, comparing with futures contracts on Chicago Board of Trade and Intercontinental Exchange. Results suggest that using the local exchange is more efficient in risk management.

Keywords:

Hedge Effectiveness; Hedge Ratio; Western Australia Crops

1. Introduction

Wheat, barley, and canola are the most important agricultural products of Western Australia (WA). Due to the small population and low domestic demand, a large proportion of agricultural products are exported to overseas markets (DAFWA 2000). Price volatilities in international markets could result in large revenue loss for WA producers. One way to manage price risk is hedging by futures contracts. In order to hedge against adverse price changes, the first step for crop producers is to select the suitable futures contract. In other words, producers encounter the key question of hedge effectiveness evaluation.

Hedge effectiveness is a determinant in explaining the success of futures contracts (Pennings and Meulenberg, 1997). Two popular methods are applied to evaluate the hedge effectiveness based on risk-minimizing and utility-maximizing objectives. Based on risk-minimizing objective, Ederington (1979) defined the hedge effectiveness as the percentage of reduction in variance of portfolio, while Cecchetti et al. (1988) evaluated it in terms of utility-maximizing objective or certainty equivalent return to incorporate individual hedger’s risk tolerance into hedge decisions.

Previous studies have measured the hedge effectiveness trying to determine the most effective hedge strategies. Ederington (1979) evaluated the effectiveness of new futures markets of Government National Mortgage Association (GNMA) and Treasure Bill (T-Bill) as a vehicle to hedge the interest rate changes. He proposed the percentage of variance reduction method as the ratio of the minimum variance with the optimal combined hedge position to the variance of the un-hedged position to measure the hedge effectiveness. Results indicated that the GNMA futures market was a more effective instrument for risk avoidance than the T-Bill market. Myers (1991) and Baillie and Myers (1991) compared the hedging effectiveness of time-varying hedge ratios and constant hedge ratios for commodity futures contracts in U.S.. Using a simulation study, they evaluated the hedge effectiveness on the mean and variance of the hedger's portfolio and the percentage reduction in the conditional variance of the portfolio return. It was found that the time-varying hedge ratios outperform constant hedge ratios. Dahlgran (2005) examined soybean hedge effectiveness through Chicago Board of Trade (CBOT) futures contracts of soybean, soybean meal and soybean oil. Comparing the R-square of OLS, mean-return of hedger's portfolio, and the percentage of price risk reduction, he found that lower transaction frequencies had higher hedge effectiveness. In order to count the hedger's level of risk aversion, which affects the choice of hedge ratios and futures contracts, a utility maximization method was applied by Brorsen et al. (1998). They compared the effectiveness of hedging hard red winter wheat through Kansas City Board of Trade (KCBT) and CBOT by comparing hedger's maximized utilities for four levels of risk aversion both through futures contracts on KCBT and CBOT. Under the conditions of transaction cost and liquidity cost, hedger's utility would be better maximized by using KCBT.

Previous researches have concentrated on evaluating the hedge effectiveness of new futures market (Ederington, 1979), comparing the hedge effectiveness of constant and time varying hedge ratios (Baillie and Myers, 1991; Myers, 1991), examining the hedge effectiveness of different exchanges (Dahlgran, 2005). However, little attention has been paid to the hedge effectiveness of Australian agricultural commodities. This paper reviews the hedge effectiveness of domestic and international futures contracts for WA producers including the futures contracts on Australian Security Exchange (ASX), Chicago Board of Trade (CBOT), and Intercontinental Exchange (ICE). As the most closely related futures contracts for WA hedger, ASX has lower liquidity and lower trading volume, which suggest that the ASX may be not the most effective way for WA hedgers to against price risk.

The organization of the paper is as follows: section 2 presents the methodology, section 3 describes the data and initial analysis, section 4 contains results of hedge ratios and hedge effectiveness. This paper concludes with a summary of the results and their implications.

2. Methods

Three methods are employed to estimate hedge ratios: ordinary least squares (OLS) based model, bivariate vector autoregression (VAR) model, and vector error-correction model (VECM). The effectiveness of these hedge ratios is evaluated by risk reduction model and utility maximization model.

The OLS model

The OLS model is the classical hedging approach that estimates the hedge ratio through a linear regression of changes in spot prices on changes in futures prices. Following Junkus and Lee (1985) and Ditsch and Leuthold (1996), let P_t^s and P_t^f be the natural logarithm of spot and futures prices, respectively. The minimum-variance constant hedge ratio is equivalent to the slope coefficient in the OLS:

$$\Delta P_t^s = \alpha + h^* \Delta P_t^f + \varepsilon_t \quad (1)$$

where Δ indicates the changes in the prices over the period, t represents the time period, and ε_t represent random error assumed to be normally distributed with mean of 0 and variance of σ^2. The constant hedge ratio is represented by h^*.

The bivariate VAR model

One aspect of the OLS regression model's invalidity is that the residual series are autocorrelated. Following Herbst et al. (1989), in order to eliminate the serial correlation, the spot and futures prices are modeled under a bivariate VAR as follows:

$$\Delta P_t^s = c_s + \sum_{i=1}^{k} \beta_{si} \Delta P_{t-i}^s + \sum_{i=1}^{k} \theta_{si} \Delta P_{t-i}^f + \varepsilon_{st} \qquad (2a)$$

$$\Delta P_t^f = c_f + \sum_{i=1}^{k} \beta_{fi} \Delta P_{t-i}^s + \sum_{i=1}^{k} \theta_{fi} \Delta P_{t-i}^f + \varepsilon_{ft} \qquad (2b)$$

where c_s and c_f are the intercepts, and β_{si}, β_{fi}, θ_{si} and θ_{fi} are parameters; ε_{st} and ε_{ft} are independently identically distributed (i.i.d) random vectors and k is the number of lags used for the variable. Let $Var(\varepsilon_{st}) = \sigma_{ss}$, $Var(\varepsilon_{ft}) = \sigma_{ff}$, and $Cov(\varepsilon_{st}, \varepsilon_{ft}) = \sigma_{sf}$, the hedge ratio is computed as:

$$h^* = \sigma_{sf} / \sigma_{ff} \qquad (3)$$

Apart from the examination o long-run co-movements of commodity prices, we explore the short-run dynamics by performing multivariate Granger-causality tests for co-integrating systems. Causality was conducted based on Granger's (1969) approach. This test is based on an F statistics, which tests whether lagged information on a variable P_t^f provides any statistical significant information about a variable P_s^f in the presence of lagged P_t^f. In Equation (2), if θ_{si} equal to zero, the P_t^f does no Granger cause P_s^f, and vice versa.

The VECM model

The VAR model ignores the possibility that spot and futures prices could be cointegrated. It has been frequently discovered by previous works that these two prices are cointegrated (Ghosh, 1993;Lien, 1996). The cointegration between two price series is an evidence of a long run relationship between them and consequently cointegration is a necessary condition for market efficiency. Absence of cointegration would suggest that the futures market is not efficient because it provides little information about movement in cash prices (Ali and Gupta, 2011;Aulton et al., 1997).

In order to account for the long-run equilibrium between spot and futures prices, the error-correction term should be added into VAR model. Equation (2) is modified as:

$$\Delta P_t^s = c_s + \sum_{i=1}^{k} \beta_{si} \Delta P_{t-i}^s + \sum_{i=1}^{k} \theta_{si} \Delta P_{t-i}^f + r_s Z_{t-1} + \varepsilon_{st} \qquad (4a)$$

$$\Delta P_t^f = c_f + \sum_{i=1}^{k} \beta_{fi} \Delta P_{t-i}^s + \sum_{i=1}^{k} \theta_{fi} \Delta P_{t-i}^f + r_f Z_{t-1} + \varepsilon_{ft} \qquad (4b)$$

where c_s and c_f are the constants, and β_{si}, β_{fi}, θ_{si}, θ_{fi}, r_s and r_f are parameters. ε_{st} and ε_{ft} are white-noise disturbance terms. Z_{t-1} is the error-correction term, which measures how the dependent variable adjusts to the previous period's deviation from long-run equilibrium:

$$Z_{t-1} = P_{t-1}^s - C - \alpha P_{t-1}^f \qquad (5)$$

where α is the cointegrating vector and C is the constant. The two-variable error-correction model expressed in Equation (4) is a bivariate VAR(k) model in first difference augmented by the error-correction term $r_s Z_{t-1}$ and $r_f Z_{t-1}$. The coefficients r_s and r_f are interpreted as the speed of adjustment parameters. The constant hedge ratio can be estimated similarly in Equation (3) using the residuals obtained from Equation (4).

Risk reduction Model

Following Ederington (1979), the returns on the hedged portfolios are estimated as:

$$r_u = P_t^s - P_{t-1}^s \qquad (6)$$
$$r_h = (P_t^s - P_{t-1}^s) - h^*\left(P_t^f - P_{t-1}^f\right) \qquad (7)$$

where r_u and r_h are the returns on the un-hedged portfolio and hedged portfolio, respectively. h^* is the optimal hedge ratio. The variance of the un-hedged and hedge portfolios is estimated as:

$$Var(U) = \sigma_s^2 \qquad (8)$$
$$Var(H) = \sigma_s^2 + h^{*2}\sigma_f^2 - 2\, h^*\sigma_{sf} \qquad (9)$$

where $Var(U)$ and $Var(H)$ are variance of un-hedged and hedged portfolios, σ_s and σ_f are standard deviation of the spot and futures prices, respectively. And σ_{sf} is the covariance of spot and futures prices. According to Ederington (1979), the effectiveness of hedging can be measured by the percentage reduction in variance of the hedged portfolio relative to the unhedged portfolio. The variance reduction can be calculated as:

$$\left(Var(U) - Var(H)\right)/Var(U) \qquad (10)$$

Utility Maximization Model

The risk reduction comparison fails to take the hedger's degree of risk aversion into account. For this reason, a utility-based compassion is considered (Cecchetti et al., 1988; Gagnon et al., 1998), which has the flexibility of accounting for the hedger's degree of risk aversion and choosing a futures contract that maximizes utility. For a given level of a hedger's risk aversion, the futures contracts are compared by its degree of utility improvement from the utility level of the unhedged portfolio. Following Gagnon et al. (1998) the problem can be written as:

$$\underset{h}{\mathrm{MAX}}[E(r_t|\Omega_{\mathrm{t-1}}) - \frac{1}{2}\phi Var(r_t|\Omega_{\mathrm{t-1}})] \qquad (11)$$

where r_t is return of hedged portfolio, ϕ is the hedger's level of risk aversion, and Ω_{t-1} is the information set available at time $t-1$.Following Brorsen et al. (1998) and Yang and Allen (2004), the risk aversion ranging from 0 to 3.

3. Results

Dataset, as tabulated in Table 1, comprises of WA daily spot price of wheat, barley, canola, and daily prices of futures contracts. The candidates of futures contract hedging wheat price risk are the ASX wheat and CBOT wheat. The candidates of futures contract hedging of barley price risk are ASX barley, CBOT corn, and ICE barley. The candidates of futures contract hedging of canola price risk are ASX canola, CBOT soybean, and ICE canola. The daily prices of these futures contracts are from 01 Jul 2008 to 31 Aug 2011 (797 observations). All prices are converted into AUD/MT.

Table 1 should be placed here

The basis is the difference between spot prices and futures prices of contracted. At the expiration of futures contract, the basis should be equal to zero (Hull, 2009). The basis, measured in Australian dollar per tonne, is illustrated in Figure 1, which is demonstrating that ASX futures contracts have smaller basis than other futures.

Figure 1 should be placed here

Spot and futures prices are transformed into natural logarithms. Following Baillie and Myers (1991) and Dawson et al. (2000), returns are multiplied by 1000 for the convenience of estimation. The price returns are summarized in Table 1. The Jarque and Bera (1980) (J-B) normality test is used to tests the joint null of zero skewness and excess kurtosis of returns. Results of J-B test indicate all returns are not normally distributed. Augmented Dickey and Fuller (1981) (ADF) unit root tests and Phillips and Perron (1988) (PP) unit root tests on the returns indicate that spot and futures prices are first difference stationary. Engle (1982) ARCH[1] effect tests, carried out by Lagrange-multiplier (LM) test (Maddala, 1992), indicate the existence of heteroscedasticity in returns. However, for the returns of ASX wheat, CBOT corn, ASX barley, and ASX canola, the heteroscedasticity is insignificant. Cointegration describes the long-run relationship between spot and futures prices. Johansen (1988) cointegration tests, both the trace test and the max eigenvalue test, are presented in Table 2. Results show that both ASX wheat futures and CBOT wheat futures have no long-term relationship with WA wheat spot. All the futures candidates for barley and canola are cointegrated with the corresponding crops.

Table 2 should be placed here

The appropriate lags length of VAR model and VECM model are selected according to the Schwarz Bayesian Criterion (SBC) and the log-likelihood ratio statistics (Enders, 2004; StataCorp, 2011). The coefficients estimated from OLS and VAR are presented in Table 3. From the coefficients, regression R-squares, and significance of the coefficients, a conclusion can be made that futures prices of ASX wheat, ASX barley, ASX canola have higher hedge ratios and greater R-squares than other contracts. ASX futures contracts have better

[1] ARCH stands for autoregressive conditional heteroskedastic

performance than contracts on CBOT and ICE. This conclusion also supported by the results from VAR on Panel B of Table 3. Granger causality test in Panel B Table 3 indicates futures prices provide statistical significant information for spot prices, which indicate there is a short-term relationship between spot and futures prices.

Table 3 should be placed here

As defined by Engle and Granger (1987) if the two series are cointegrated, an error-correction term must be include in the equation. With the cointegration testes in Table 2, the VECM is estimated by incorporating the error correction term into the VAR. The results of VECM model are presented in Table 4, showing that for equations of changes in logged spot prices. It noted that r_s is slightly greater than zero in all equations, and not significant in some equations, which indicating there is a weak long-term relationship between futures and spot prices. In line with Ghosh (1993), the constants in each model equal to zero and are statistically insignificant proved that the process is not generated by a linear trend.

Table 4 should be placed here

Using the residual unconditional variance and covariance, the hedge ratios for VAR and VECM are computed in Table 5, together with the hedge ratio estimated from OLS model. Unfortunately, the hedge ratios estimated from VECM are not greater than that obtained from VAR and OLS model.

Table 5 should be placed here

Following Myers (1991), hedge performance tests are carried out using a simulation study. A WA hedger is assumed to hold one metric tonne commodity continuously over the sample period. The hedger hedges price fluctuations of their portfolio by selling futures contracts. The number of futures contracts is determined by the computed hedge ratios. The hedger's income at the end of the sample period equals the cash value of the commodity plus or minus any gains or loss on futures. Performance is evaluated using the risk reduction and utility maximization approaches over the hedge period.

The hedge effects of risk reduction are presented in Table 6 Panel A. The variance of unhedged portfolio was taken as a benchmark. Although all futures contracts reduce the portfolio variance, it is shown that ASX wheat, ASX barley and ASX canola reduce more risk than other futures contracts. The risk reduction results prove that the risk of hedge portfolio is only slightly lower than unhedged portfolio. This is one of the reasons why farmers have little interests on hedging, which is consistent with Pannell et al. (2008).

Table 6 Panel B illustrates utility comparisons associated with different futures contracts for a range of risk aversion coefficients ϕ from 0 to 3. The utility of unhedged position is presented as a benchmark. Following Gagnon et al. (1998), the utility levels for un-hedged and hedged portfolios are computed from the portfolio's mean and variance of returns. Consistent with risk reduction method across all degree of risk aversion, the ASX wheat, ASX barley and ASX canola contracts are more effective than other futures contracts in terms of utility maximization. When hedger's risk aversion level is lower than 1, CBOT corn is more effective. When risk aversion level increased, ASX barley should be employed.

For all risk aversion levels and all futures contracts, hedging improves the hedger's utility compared to the unhedged portfolio. When the risk aversion level increased, both the expected utility of un-hedge portfolio and hedged portfolio are decreased. However, the expected utilities are negative for all risk aversion levels. This could be another reason why farmers have so little interests in hedging , which is also in line with Pannell et al. (2008).

Figure 1 should be placed here
Table 6 should be placed here

4. Discussion

The present paper studied the futures contracts selection by comparing hedge effectiveness for alternative futures contracts from ASX, CBOT and ICE, based on risk reduction method and utility maximum method.

The optimal hedge ratios were estimated using OLS, VAR, and VECM models. Results suggest that despite being thinly traded contracts, ASX wheat, ASX barley, and ASX canola futures contracts have higher hedge ratios and higher hedge effectiveness for WA hedgers. This suggests the local exchange is more efficient in risk management for WA hedgers.

In this paper, the hedge effectiveness of futures contracts indicates futures contracts can slightly reduce portfolio risk and improve hedger's utility, which supply additional supports for Simmons (2002) and Pannell et al. (2008) to explain why farmers have little interest in futures markets.

Nevertheless, the trading volume, transaction costs and foreign exchange rate may also have influence on hedge effectiveness. These questions are left to future research.

References

Ali, J., and Gupta, K. B. (2011). Efficiency tests of agricultural commodity futures markets in India: Evidence from cointegration and causality tests. *Agricultural Finance Review* **71**, 162-178.

Aulton, A. J., Ennew, C. T., and Rayner, A. J. (1997). Efficiency tests of futures markets for UK agricultural commodities. *Journal of Agricultural Economics* **48**, 408-424.

Baillie, R. T., and Myers, R. J. (1991). Bivariate Garch Estimation of the Optimal Commodity Futures Hedge. *Journal of Applied Econometrics* **6**, 109-124.

Brorsen, B. W., Buck, D. W., and Koontz, S. R. (1998). Hedging hard red winter wheat: Kansas City versus Chicago. *Journal of Futures Markets* **18**, 449-466.

Cecchetti, S. G., Cumby, R. E., and Figlewski, S. (1988). Estimation of the Optimal Futures Hedge. *Review of Economics and Statistics* **70**, 623-630.

DAFWA , D. o. A. a. F., Goverment of Western Australia (2000). The Wheat Book: Principles and Practice.

Dahlgran, R. A. (2005). Transaction frequency and hedging in commodity processing. *Journal of Agricultural and Resource Economics* **30**, 411-430.

Dawson, P. J., Tiffin, A. L., and White, B. (2000). Optimal hedging ratios for wheat and barley at the LIFFE: A GARCH approach. *Journal of Agricultural Economics* **51**, 147-161.

Dickey, D. A., and Fuller, W. A. (1981). Likelihood Ratio Statistics for Autoregressive Time-Series with a Unit-Root. *Econometrica* **49**, 1057-1072.

Ditsch, M. W., and Leuthold, R. M. (1996). Evaluating the Hedging Potential of the Lean Hog Futures Contract. **OFOR Paper Number 96-03**.

Ederington, L. H. (1979). Hedging Performance of the New Futures Markets. *Journal of Finance* **34**, 157-170.

Enders, W. (2004). Applied Econometric Time Series (Second Edition).

Engle, R. F. (1982). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United-Kingdom Inflation. *Econometrica* **50**, 987-1007.

Engle, R. F., and Granger, C. W. J. (1987). Cointegration and Error Correction - Representation, Estimation, and Testing. *Econometrica* **55**, 251-276.

Gagnon, L., Lypny, G. J., and McCurdy, T. H. (1998). Hedging foreign currency portfolios. *Journal of Empirical Finance* **5**, 197-220.

Ghosh, A. (1993). Cointegration and Eroor Correction Models: Intertemporal Causality between Index and Futures Prices. *Journal of Futures Markets* **13**, 193-198.

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric Models and Cross-Spectral Methods. *Econometrica* **37**, 414-&.

Herbst, A., Kare, D., and Marshall, J. (1989). A time varying convergence adjusted minimum risk futures hedge ratio. *Advances in Futures and Options Research* **6**, 137-155.

Hull, J. (2009). Options, Futures, and other Derivatives. *Upper Saddle River, NJ : Prentice Hall*.

Jarque, C. M., and Bera, A. K. (1980). Efficient Tests for Normality, Homoscedasticity and Serial Independence of Regression Residuals. *Economics Letters* **6**, 255-259.

Johansen, S. (1988). Statistical-Analysis of Cointegration Vectors. *Journal of Economic Dynamics & Control* **12**, 231-254.

Junkus, J. C., and Lee, C. F. (1985). Use of 3 Stock Index Futures in Hedging Decisions. *Journal of Futures Markets* **5**, 201-222.

Lien, D. H. D. (1996). The effect of the cointegration relationship on futures hedging: A note. *Journal of Futures Markets* **16**, 773-780.

Maddala, M. S. (1992). Introduction to Econometrics. *2nd ed. New York: Macmillan*, 250-252.
Myers, R. J. (1991). Estimating Time-Varying Optimal Hedge Ratios on Futures Markets. *Journal of Futures Markets* **11**, 39-53.
Pannell, D. J., Hailu, G., Weersink, A., and Burt, A. (2008). More reasons why farmers have so little interest in futures markets. *Agricultural Economics* **39**, 41-50.
Pennings, J. M. E., and Meulenberg, M. T. G. (1997). Hedging efficiency: A futures exchange management approach. *Journal of Futures Markets* **17**, 599-615.
Phillips, P. C. B., and Perron, P. (1988). Testing for a Unit-Root in Time-Series Regression. *Biometrika* **75**, 335-346.
Simmons, P. (2002). Why do farmers have so little interest in futures markets? *Agricultural Economics* **27**, 1-6.
StataCorp, L. (2011). Stata time-series Reference manual release 12. *A State Press Publication StataCorp Lp, College Station, Texas*, 607-609.
Yang, W., and Allen, D. E. (2004). Multivariate GARCH hedge ratios and hedging effectiveness in Australian futures markets. *Accounting and Finance* **45**, 301-321.

Table 1 Descriptive statistics

	Wheat Returns			Barley Returns				Canola Returns			
	Spot	Futures		Spot	Futures			Spot	Futures		
		ASX	CBOT		ASX	CBOT	ICE		ASX	CBOT	ICE
Mean	-0.181	0.370	-0.024	-0.167	-0.688	0.206	-0.207	-0.281	-0.509	-0.011	-0.125
Std. Dev.	17.830	15.923	31.753	16.353	28.348	30.555	24.839	13.471	16.062	28.891	19.127
Skewness	-0.760	-11.683	-0.184	0.675	-7.396	-0.238	2.101	0.399	-9.807	-0.709	-0.655
	(0.000)	(0.000)	(0.036)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Kurtosis	12.994	255.18	4.219	11.476	135.65	4.664	33.953	8.860	195.86	14.625	9.293
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
J-B test	3376	2100000	52.416	2440	590000	96.878	31000	1158	1200000	4434	1330
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ADF test	-32.374	-28.421	-28.841	-26.808	-30.334	-26.941	-27.274	-28.658	-28.185	-28.260	-27.877
PP test	-32.227	-28.422	-28.838	-27.186	-30.273	-26.972	-27.342	-28.655	-28.221	-28.258	-27.878
LM test	28.631	0.001	0.037	20.694	0.000	13.334	0.260	3.634	0.012	138	33.254
	(0.000)	(0.969)	(0.848)	(0.000)	(0.987)	(0.000)	(0.610)	(0.057)	(0.912)	(0.000)	(0.000)

Note: J-B test is the Jarque and Bera (1980) test for normality. ADF test is the Augmented Dickey-Fuller unit-root test (Dickey and Fuller, 1981; Said and Dickey, 1984). The 1% critical value of ADF test is -3.430, 5% critical value is -2.860. PP test is the Phillips and Perron (1988) unit root test. The 1% critical value of PP test is -3.430, and the 5% critical value is -2.860. LM test is the Lagrange-multiplier test for ARCH effects, which was presented in Johansen (1995). P-value in parentheses. Statistically significant coefficients are marked with *.

Table 2 Johansen Cointegration Test

Panel A: trace test

		Wheat		Barley			Canola		
H_0: Rank $\leq$ r	H_1: Rank $>$ r	ASX	CBOT	ASX	CBOT	ICE	ASX	CBOT	ICE
0	0	8.967	14.241	33.468*	20.272*	19.928*	18.17*	19.897*	21.599*
1	1	2.696	2.118	4.723	3.388	3.987*	3.831*	2.970	3.804*

Panel B: Max eigenvalue test

		Wheat		Barley			Canola		
H_0: Rank $\leq$ r	H_1: Rank $>$ r	ASX	CBOT	ASX	CBOT	ICE	ASX	CBOT	ICE
0	0	6.272	12.123	28.740*	16.884*	15.941	14.275	16.927*	17.795*
1	1	2.696	2.118	4.728*	3.388	3.987*	3.831*	2.970	3.804

Note: cointegration tests following (Johansen, 1988): $H_0: r = 0$, there are no cointegrating vectors, $H_1: r \leq 1$, the number of cointegrating vectors is not greater than 1. For tract test, the 5% critical values for H_0 and H_1 are 18.17 and 3.74 respectively. For max eigenvalue test, 5% critical values for H_0 and H_1 are 16.87 and 3.74, respectively. The null is rejected when the test statistic is greater than the critical value. The rejected hypothesizes are marked with *.

Table 3 Estimation of OLS and VAR

Panel A: OLS estimation

		Wheat		Barley			Canola		
		ASX	CBOT	ASX	CBOT	ICE	ASX	CBOT	ICE
OLS	Coefficient	0.052	-0.014	0.143*	0.028	0.030	0.062*	-0.005	0.040
		(0.192)	(0.463)	(0.000)	(0.160)	(0.227)	(0.037)	(0.767)	(0.121)
	Constant	-0.200	-0.185	-0.068	-0.176	-0.170	-0.250	-0.288	-0.283
		(0.752)	(0.774)	(0.906)	(0.771)	(0.782)	(0.601)	(0.556)	(0.567)
	R-square	0.002	0.001	0.060	0.003	0.002	0.005	0.000	0.003

Panel B: VAR estimation

			Wheat		Barley			Canola		
			ASX	CBOT	ASX	CBOT	ICE	ASX	CBOT	ICE
VAR	Coefficient	S(1)	-0.147*	-0.097*	0.009	0.048	0.055	-0.021	-0.051	-0.097*
			(0.000)	(0.007)	(0.811)	(0.178)	(0.124)	(0.557)	(0.154)	(0.007)
		S(2)	0.013	0.001	0.016	0.049	0.058	0.018	0.017	-0.031
			(0.721)	(0.979)	(0.651)	(0.167)	(0.108)	(0.615)	(0.625)	(0.317)
		F(1)	0.076	0.297*	0.067*	0.040*	-0.025	0.016	0.145*	0.353*
			(0.053)	(0.000)	(0.002)	(0.042)	(0.310)	(0.593)	(0.000)	(0.000)
		F(2)	0.100*	-0.027	0.065*	0.026	-0.013	0.070*	0.042*	0.084*
			(0.011)	(0.176)	(0.003)	(0.182)	(0.584)	(0.019)	(0.014)	(0.001)
	Constant	C	-0.302	-0.222	-0.073	-0.167	-0.141	-0.257	-0.311	-0.284
			(0.628)	(0.682)	(0.901)	(0.782)	(0.818)	(0.590)	(0.503)	(0.509)
Granger Causality Wald Test			10.079*	306.93*	16.603*	6.095*	1.352	5.786*	86.417*	253.4*
			(0.006)	(0.000)	(0.000)	(0.047)	(0.509)	(0.045)	(0.000)	(0.000)

Note: The results of VAR model are a bivariate VAR(2) model. Panel B presents the results of Equation (2a). P-values are presented in the parentheses with the significance at 95% level, the statistically significant coefficients are marked with *. S(*i*) and F(*i*) represent the coefficient of lag *i* for the differenced logarithm of spot and futures prices, respectively. C represents the constant.

Table 4 Estimation of VECM

Coefficient	ASX Wheat	CBOT Wheat	ASX Barley	CBOT Corn	ICE Barley	ASX Canola	CBOT Soybean	ICE Canola
Panel A: Cointegrating Equation								
r_s	-0.009 (0.055)	-0.001 (0.575)	0.006* (0.028)	-0.007 (0.052)	-0.002 (0.420)	0.003 (0.373)	-0.008* (0.037)	-0.008* (0.048)
S(1)	-0.139* (0.000)	-0.121* (0.000)	0.014 (0.697)	0.057 (0.113)	0.061 (0.090)	-0.024 (0.510)	-0.023 (0.495)	-0.039 (0.212)
F(1)	0.072 (0.066)	0.298* (0.000)	0.063* (0.003)	0.037 (0.062)	-0.026 (0.296)	0.017 (0.565)	0.143* (0.000)	0.345* (0.000)
C	0.000 (0.909)	0.000 (0.702)	0.000 (0.851)	0.000 (0.971)	0.000 (0.741)	0.000 (0.752)	0.000 (0.699)	0.000 (0.748)
χ^2	23.441* (0.000)	324* (0.000)	14.932* (0.005)	10.624* (0.031)	4.320 (0.365)	1.730 (0.786)	85.882* (0.000)	244* (0.000)
Panel B: Cointegrating Equation (Z_{t-1})								
P^s_{t-1}	1	1	1	1	1	1	1	1
P^f_{t-1}	-0.481 (0.080)	0.210 (0.625)	-1.364 (0.000)	-0.466 (0.027)	-1.396 (0.000)	-0.992 (0.000)	-0.086 (0.644)	-0.244 (0.180)
Cons	-2.980	-6.773	1.841	-2.965	1.683	-0.086	-5.738	-4.762

Note: Panel B presents the results of Equation (4a). The coefficients of cointegration equation are r_s of equation (4a). The S(*i*) and F(*i*) represent the coefficients of lag *i* for the difference logarithm of spot and futures prices, respectively. C is the constant. P-values are presented in the parentheses with the significance at 95% level, the statistically significant coefficients are marked with *. χ^2 represents the Wald test for the equation. Panel B represents the results of cointegration equation of spot and futures prices $Z_{t-1} = P^s_{t-1}$-C-αP^f_{t-1}.

Table 5 Hedging Ratios from OLS, VAR and VECM

	Wheat		Barley			Canola		
	ASX-wheat	CBOT-wheat	ASX-barley	CBOT-corn	ICE-barley	ASX-canola	CBOT-soybean	ICE-canola
OLS	0.052	-0.014	0.143	0.028	0.030	0.062	-0.005	0.040
VAR	0.072	-0.002	0.437	0.026	0.028	0.061	-0.002	0.041
VECM	0.059	-0.002	0.146	0.028	0.031	0.062	-0.004	0.038

Table 6 Hedging Effectiveness

Panel A: Risk-return hedging performance comparison

Variance Reduction (%)	Wheat		Barley			Canola		
	ASX wheat	CBOT wheat	ASX barley	CBOT corn	ICE barley	ASX canola	CBOT soybean	ICE canola
OLS	0.26%	0.00%	5.86%	0.35%	0.29%	0.30%	0.00%	0.24%
VAR	0.28%	0.00%	-10.81%	0.34%	0.28%	0.31%	0.00%	0.24%
VECM	0.28%	0.00%	5.89%	0.38%	0.30%	0.31%	0.00%	0.24%

Panel B: Utility Maximization hedging performance comparison

Risk Averse Level		Wheat		Barley			Canola		
		ASX wheat	CBOT wheat	ASX barley	CBOT corn	ICE barley	ASX canola	CBOT soybean	ICE canola
ϕ = 0	Unhedged	-0.058	-0.059	-0.452	-0.046	-0.478	-0.183	-0.187	-0.187
ϕ = 0.1	Unhedged	-1.588	-1.616	-2.507	-2.150	2.611	-6.149	-6.289	-6.402
	OLS	-1.584	-1.616	-1.184	-0.845	-1.292	-2.908	-2.988	-3.038
	VAR	-1.584	-1.616	-1.314	-0.846	-1.298	-2.908	-2.988	-3.038
	VECM	-1.584	-1.616	-1.184	-0.845	-1.292	-2.908	-2.988	-3.038
ϕ = 0.5	Unhedged	-7.709	-7.844	-8.727	-8.566	-9.142	-28.015	-28.696	-29.262
	OLS	-7.689	-7.844	-4.111	-4.042	-4.548	-13.807	-14.191	-14.440
	VAR	-7.687	-7.844	-4.760	-4.043	-4.576	-13.806	-14.191	-14.440
	VECM	-7.688	-7.844	-4.110	-4.041	-4.548	-13.806	-14.191	-14.440
ϕ = 1.0	Unhedged	-15.359	-15.630	-16.501	-16.586	-17.306	-55.347	-56.705	-57.837
	OLS	-15.319	-15.630	-7.771	-8.038	-8.618	-27.432	-28.196	-28.692
	VAR	-15.316	-15.629	-9.067	-8.039	-8.674	-27.430	-28.195	-28.692
	VECM	-15.317	-15.629	-7.769	-8.036	-8.617	-27.430	-28.196	-28.693
ϕ =2.0	Unhedged	-61.762	-31.201	-32.050	-32.625	-33.634	-110.011	-112.722	-114.986
	OLS	-30.581	-31.201	-15.089	-16.029	-16.758	-54.680	-56.204	-57.197
	VAR	-30.573	-31.120	-17.681	-16.032	-16.870	-54.677	-56.204	-57.197
	VECM	-30.576	-31.200	-15.085	-16.025	-15.757	-54.677	-56.204	-57.199
ϕ =3.0	Unhedged	-92.364	-46.772	-47.598	-48.665	-49.962	-164.674	-169.839	-172.135
	OLS	-45.842	-46.772	-22.408	-24.020	-24.898	-81.929	-84.213	-85.702
	VAR	-45.830	-46.771	-26.296	-24.024	-25.067	-81.924	-84.212	-85.701
	VECM	-45.836	-46.771	-22.402	-24.015	-24.896	-81.824	-84.212	-85.705

Note: This table presents hedging effectiveness comparison from utility maximization method. The utility levels for un-hedged and hedged portfolio are computed from the portfolio's mean and variance of return over the sample period.

Figure 1 Wheat, barley, and canola prices

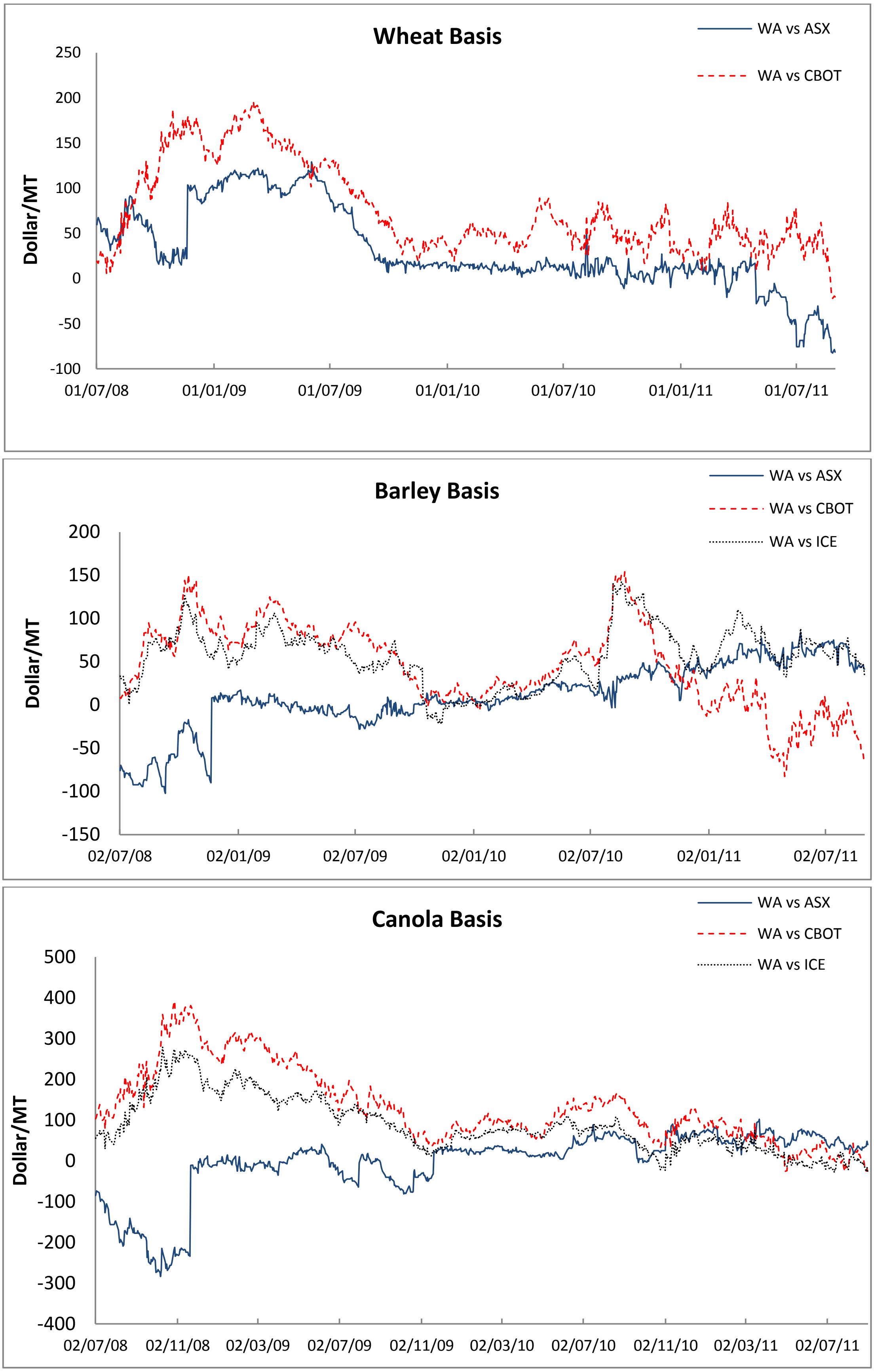

Figure 2 Utility-maximization Hedging Performance Comparison