The Role of Long Memory in Hedging Strategies for Canadian Agricultural Futures

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This research paper investigates whether ICE futures contracts are an effective and affordable strategy to manage price risk for Canadian commodity producers in recent periods of high price volatility. Long memory in volatility is found to be present in cash and futures prices for canola and western barley. This finding is incorporated into the hedging strategy by estimating hedge ratios using a FIAPARCH model. Findings indicate that the ICE futures contracts for canola is an effective and affordable means of reducing price risk for canola producers and should be considered as part of a price risk management strategy. On the other hand, the findings indicate that the ICE futures contract for western barley is not as effective as a means of reducing price risk for western barley producers, however it is affordable. At the current time, western barley producers should consider alternative means of price risk management, however the ICE futures contract should be reconsidered after modifications to contract specifications come into effect.

INTRODUCTION

Commodity producers face many risks each crop year. These risks include: production risk from weather, pests and diseases; political risk from domestic and foreign governments; relationship risk from business and trading partners; human risk from illness, carelessness, or a life crisis; and price risk from market prices and exchange rates (Hardaker et al 2004). Producers have many options when it comes to managing each of these risks. For example, methods to

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manage production risk include purchasing crop insurance, selecting disease and drought resistant varieties, and maintaining good crop rotations. Methods to manage price risk include short selling futures contracts (hedging), purchasing options, entering forward or basis contracts, and participating in government programs.

The focus of this paper is to gain an understanding of managing market price risk for canola and western barley using the Canadian based futures contracts offered by InterContenental Exchange Futures Canada (ICE) during the recent period of high (price) volatility. The recent period of interest is the 2007 crop year[2]. In the early 2000s, the price of canola fluctuated between 235 and 450 dollars per tonne, a 215 dollar spread. In the 2007 crop year the price of canola and its range increased substantially, with the cash price of canola ranging from 411 dollars to 774 dollars per tonne, a 363 dollar spread. In the early 2000s, the price of western barley fluctuated between 100 and 200 dollars per tonne. In the 2007 crop year the price of western barley also increased substantially, with the cash price of western barley ranging from 170 to 260 dollars per tonne.

The first research question of interest is whether the ICE futures contracts are an effective and affordable strategy to manage price risk for Canadian commodity producers. The role of long memory in hedging effectiveness is also investigated. Three methods of calculating hedge ratios are considered – one-to-one, OLS, and several variations of GARCH (specifically FIAPARCH). In light of the recent period of high (price) volatility, the 2007 crop year is used as an out-of-sample forecast to evaluate the effectiveness and affordability of each hedging strategy. The effectiveness is measured by the reduction in portfolio variance. The affordability is evaluated by comparing the per tonne cost of transactions and margin calls with the per tonne cost of production for canola and western barley.

[2] A crop year runs from August first of one year through July thirty-first of the next.

This research builds on findings by several articles which focus on hedging with Canadian traded commodities. Sephton (1993a) found the constant correlation GARCH hedging strategy to outperform the traditional regression approach (OLS) for canola and feed wheat by one percent in the 1981 crop year, albeit the outperformance was not significantly different from zero. Sephton (1993b) also found the multivariate GARCH hedging strategy to outperform the OLS strategy for feed barley, canola and feed wheat in the 1988 crop year. The first study evaluated performance using the reduction in portfolio variance and the second study evaluated performance using a combination of reduction in portfolio variance and utility. Using the same dataset as Sephton (1993b), Sephton (1998) compared the bivariate MARKOV hedging strategy with the constant conditional correlation GARCH and OLS hedging strategy for canola, feed barley, and feed wheat. The GARCH strategy was found to outperform the OLS strategy by 11 percent for canola and both the GARCH and OLS strategy outperformed the MARKOV strategy for all three commodities however, in low variance states the MARKOV strategy was found to outperform the GARCH and OLS strategy. More recently, Amaroso, Unterschultz, and Nilsson (2009) estimated VAR hedge ratios for canola using data specific to each of the three prairie provinces for the crop years from 1998 through 2006. The study evaluated performance using the percentage reduction in portfolio variance in comparison to no hedge, with the average effectiveness being 80, 80.6 and 78.6 percent for Manitoba, Saskatchewan, and Alberta respectively.

This research also builds on findings by several articles which focus on hedging with non-Canadian traded commodities. Baillie and Myers (1991) found bivariate GARCH hedge ratios to outperform constant hedge ratios for all six commodities in the study (beef, coffee, corn, cotton, gold, soybean) for both the in-sample results (1982) and out-of-sample results (1986), with the conditional portfolio variance reduction ranging from 52 to 2 percent in comparison to no hedge. Lien, Tse and Tsui (2002) found OLS to outperform constant correlation GARCH hedge ratios for ten contracts, five being agricultural commodities (soybean oil, wheat, crude oil, corn, and cottonseed) between 1988 and 1998. They measured performance by portfolio variance reduction. Bystrom (2003) found the unconditional OLS method of estimating hedge ratios to outperform the constant conditional correlation bivariate GARCH model and the orthogonal GARCH model for short-term electricity spot and futures traded on the Nordic Power Exchange between 1996 and 1999.

The main contribution of this research paper is that it extends work on long-memory in commodity futures to the Canadian environment. Long-memory has been found to exist in crude oil price volatility for futures traded over the New York Mercantile Exchange (NYME) and the International Petroleum Exchange[3] (IPE) (Brunetti and Gilbert 2000), aluminum and copper price volatility for futures traded over the London Metal Exchange (LME) (Figuerola-Ferretti and Gilbert 2008), and for various agricultural commodities traded on the Chicago Board of Trade[4] (CBOT), Chicago Mercantile Exchange (CME), Kansas City Board of Trade (KCBOT), New York Board of Trade (NYBOT), and the Coffee, Sugar and Cocoa Exchange (CSCE)[5] (Sephton 2009, Coakley, Dollery and Kellard 2008, Jin and Frechette 2004, and Crato and Ray 2000). This paper tests for fractional integration in Canadian commodity price volatility and incorporates the findings into the hedging model selection. The models under consideration include GARCH, Asymmetric Power ARCH, Fractionally Integrated GARCH (FIGARCH) or the Fractionally Integrated Asymmetric Power ARCH model.

[3] The International Petroleum Exchange was purchased by the ICE in 2001.
[4] The CBOT and the CME merged in July 200, however they were separate companies for the studies by Jin and Frechett (2004) and Sephton (2009).
[5] The CSCE was a subsidiary of the NYBOT during the period studied by Crato and Ray (2000). The NYBOT merged and was renamed ICE Futures US in 2007.

Even a small improvement to price risk management for Canadian commodities traded on ICE can have a large impact on the many users of the futures contract. This paper contributes to the large body of literature on price risk management via hedging in several ways. First, the paper focuses on the performance of various hedging models during the extreme price volatility of the 2007 crop year. Second, the paper tests for fractional integration in Canadian commodities, which has not been studied to date. Third, there are limited applications of sophisticated risk management strategies to Canadian commodity markets. Lastly, this research evaluates whether the FIAPARCH specification is an affordable risk management strategy for commodity producers, something rarely considered in agricultural risk management research.

The remainder of this paper is organized as follows. The next section provides a brief historical review of the ICE as well as industry information on canola and western barley. This is followed by the derivation of each of the three hedging strategies. A description of the data follows. The paper progresses with the estimation of each hedge ratio and an evaluation of their effectiveness. An evaluation of the affordability of the each hedge strategy when taking into account transactions costs and margin calls follows. The paper concludes with remarks as to the effectiveness and affordability of each hedging strategy when used to manage price risk for the 2007 crop year.

BACKGROUND

ICE Futures Canada[6] was established as the Winnipeg Grain Exchange in 1887 (Kearns 2002), operating as a cash market for wheat, oats and barley. In 1888 the Commodity Exchange established a call market for wheat, oats, barley, peas, corn, rye, flour, bran and oatmeal (WCE

[6] Commodity Exchange will be used in place of the current ICE Futures Canada (previously the Winnipeg Commodity Exchange and the Winnipeg Grain Exchange) throughout the historical sections of the paper.

Exchange 2005). Eighteen years after being established, the Commodity Exchange expanded into the futures market, the first being for wheat (1904) followed closely by oats (1904), flaxseed (1904), barley (1913) and rye (1917). The Commodity Exchange continued to expand into new futures markets including canola (1963), gold (1972), feed wheat for domestic use (1974), and Government of Canada bonds and Treasury bills (1981) (Kearns 2002).

Over time, the Commodity Exchange entered into new markets as well as exited from others. In the early 2000s the Commodity Exchange traded futures contracts for canola, flaxseed, oats, feed wheat, western barley and field peas as well as traded option contracts for canola, flaxseed, feed wheat and western barley (Canada Grains Council 2001). Today, ICE[7] trades futures contracts for canola and western barley as well as option contracts for canola. ICE provides an important service for producers of agricultural commodities by creating an open market for canola and western barley (described below), allowing producers and processors to hedge and non-producers to speculate.

Barley was introduced to the Commodity Exchange in 1887 as a cash market, followed by a call market in 1888. In 1913 the Commodity Exchange introduced a futures market for barley (Kearns 2002). With the introduction of the Canadian Wheat Board as a monopoly seller of wheat and barley for human consumption, the Commodity Exchange facilitated a futures market for feed barley only (western barley). ICE has maintained and is currently offering a western barley futures contract (note that western barley options are not offered).

Barley is used as malt, livestock feed or food depending on the variety and quality. Canadian barley production amounted to 11.8 million metric tonnes in the 2007 crop year. Of the total quantity of barley produced, 1.5 million metric tonnes of barley were exported (FAO 2009) with the majority of exports being malting rather than feed barley (Government of Manitoba 2009).

[7] ICE acquired the WCE in August 2007.

The major importers of Canadian malting barley are the United States, China, Mexico, South Africa, Columbia, and Japan (The Alberta Barley Commission 2009). The remaining 10.3 million metric tonnes of barley is either used as feed for domestically produced cattle, hogs, and chicken or is saved for seed.

All barley produced in Western Canada (Manitoba, Saskatchewan, Alberta and part of British Columbia) is marketed by the Canadian Wheat Board, except for barley that is sold domestically as feed for livestock. With over ninety percent of barley being produced in Western Canada (Agriculture and Agrifood Canada 2007), the Canadian Wheat Board markets the vast majority of Canadian barley exports. The Canadian Wheat Board has acted as a single desk seller of barley since 1949 except for a brief period between August and September of 1993 (Dakers and Frechette 1998). For this reason, there is no need for a Canadian malt barley futures contract, only a feed barley contract.

Western barley contracts are available through ICE Futures Canada for delivery in the months of March (H), May (K), July (N), October (V), and December (Z). The average daily trade volume for the 2007 crop year was 299 contracts and the average open interest was 7,216 contracts. One contract is equivalent to twenty tonnes of non-commercially cleaned No.1 Canadian western barley with a dockage[8] not exceeding two percent. There are seven delivery regions, each with a specified discount or premium, ranging from a two-dollar discount in the Eastern region to a six-dollar premium in the Western region[9]. The minimum price fluctuation is 0.10 dollars per tonne and the daily price limit is 15 dollars per tonne. Deliverable specifications,

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[8] The Canada Grain Act defines dockage as, “any material intermixed with a parcel of grain, other than kernels of grain of a standard of quality fixed by or under this Act for a grade of that grain, that must and can be separated from the parcel of grain before that grade can be assigned to the grain.”

[9] This description of the delivery regions is accurate for the period of study. As of the fall, 2009 the delivery region will be in southern Alberta only.

trading hours and other information on the western barley futures contract can be found on the ICE Futures Canada website.

Figure 1 below shows the cash (black) and futures (blue) price for western barley over the past eight years. The crop years between 1993 and 2006 precede the vertical grey line. The 2007 crop year includes all data points to the right of the vertical grey line. The correlation between the cash and futures price for the fifteen crop years between 1993 and 2007 is 0.772. The correlation dramatically increased in the more recent years, with the correlation between the cash and futures price for the five crop years between 2003 and 2007 being 0.944, indicating that the western barley futures contract could be part of a viable hedging strategy.

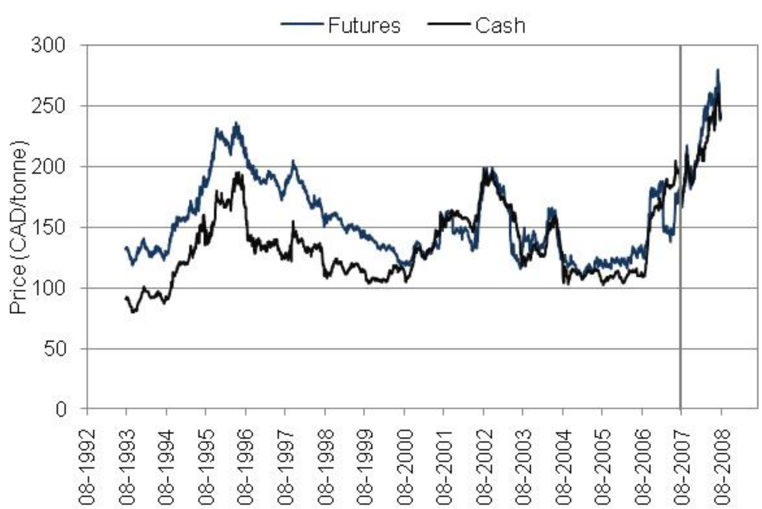

Figure 1. Cash and futures price for western barley (per metric tonne)

Canola was introduced to the futures market in 1963 by the Commodity Exchange with a Vancouver based futures contract. A Thunder Bay canola futures was introduced in 1970 but was cancelled seven years later. In 1988 the Commodity Exchange established a cash call market for canola and in 1991 canola options were added. Several interior delivery points were added to the Vancouver based futures contracts in 1994. Interior pricing of canola was introduced in 1996 and the Vancouver delivery point was eliminated in 1998. The Commodity Exchange eliminated the cash call market for canola in 1999. Canola meal entered as a futures commodity in 2001, but was eliminated in 2003 (Winnipeg Commodity Exchange 2005). In August 2007, ICE purchased the Commodity Exchange, acquiring the world's leading canola contract and is currently offering a canola futures and canola options market.

The traditional final product for canola is canola oil, an edible oil that is low in saturated fat. In addition to the traditional final product, biodiesel has been introduced as a second final product for canola. The by-product from crushing canola to produce oil is canola meal. It is used mainly as a protein supplement in animal feed.

Canola futures contracts are available through ICE Futures Canada for delivery in the months of January (F), March (H), May (K), July (N), and November (X). The average daily trade volume for the 2007 crop year was 7,763 contracts and the average open interest was 70,709 contracts. One contract is the equivalent of twenty tonnes of commercially cleaned or uncleaned, No. 1 or No. 2 canola according to Canadian Grain Commission standards. There are six delivery regions that are, after combining the south western and western regions, identical to those for western barley. The minimum price fluctuation is 0.10 dollars per tonne and the daily price limit is 45 dollars per tonne. Deliverable specifications, trading hours and other important information pertaining to canola futures contracts can be found on the ICE Futures Canada website.

Canola production in Canada amounted to 8.8 million metric tonnes in the 2007 crop year. This accounted for approximately twenty percent of worldwide canola production (FAO 2009). Within Canada, 98 percent of canola is grown in Manitoba, Saskatchewan and Alberta (Statistics Canada 2008). Canola seed is either crushed domestically or exported. In the 2006 crop year canola seed exports were 60 percent of canola seed production, which accounted for 40 percent of world canola seed exports. Major importers of Canadian canola seed are China, Japan, Mexico and the United States (Statistics Canada 2009a).

Figure 2 below depicts the cash (black) and futures (blue) price for canola over the past eight years. As with western barley, the crop years between 1993 and 2006 precede the vertical grey line. The 2007 crop year includes all data points to the right of the vertical grey line. The correlation between the cash and futures price for the fifteen crop years between 1993 and 2007 is 0.982, indicating that the canola futures contract could be part of a viable hedging strategy.

Figure 2. Cash and Futures Price for Canola (per metric tonne)

HEDGING STRATEGIES

The hedging strategy for a producer wishing to reduce price risk using the futures market is to enter a short position to offset their innate long position from producing the commodity. The hedging strategy allows a producer to use the futures market to lock in a price. The price on the day the producer enters the short position is the price he or she wishes to lock in. It follows that a producer would commence the hedging strategy on a day that he or she is happy with the price. A producer will generally enter the short position in the late spring or early summer using a fall futures. The position is entered in the spring for two reasons; first, the total seeded acres of each crop type are known so the producer is able to estimate total production and second, the price of agricultural commodities are historically higher in the late spring or early summer than the remainder of the growing season. The fall futures contract is selected because the producer will have the final product harvested by the delivery period. This allows delivery to remain a settlement option.

The scenario used to analyse the effectiveness and affordability of the hedging strategies in the 2007 crop year follows. A producer enters into a short position on the first of July[10] using the November[11] futures contract. Prior to entering the short position the producer must decide on an appropriate hedge ratio. It is often the case that a producer will hold one short position for each cash (long) position. For example, the average canola producer sows 105 hectares of canola (Wilcox 2007). Using the five-year average Canadian yield of 1.7 tonnes per hectare as the expected yield (Statistics Canada 2009b), the producer would enter 9 short positions for delivery in November (ie., short sell 9 futures contracts) to fully hedge their price. Similarly, the average producer sows 61.5 hectares of barley (Wilcox 2007). Using the five-year average Canadian yield of 3.1 tonnes per hectare as the expected yield (Statistics Canada 2009b), the producer would enter 9.5 short positions for delivery in October (ie., short sell 9.5 futures contracts) to fully hedge their price. It may not be the case that the producer would choose to hedge his or her entire production (ie., partial hedge), however for the purpose of this research a complete hedge of 9 contracts will be assumed for both canola and western barley. For a one-to-one hedging strategy the producer would sell short 9 futures contracts. The one-to-one hedge ratio is appealing due to its intuitiveness, simplicity, and minimal transactions costs but has several

[10] July is selected because the price for the fall futures is usually at a high point. This pattern is more predictable for canola than western barley.

[11] November is the fall contract for canola. November is the fall contract for western barley until it is replaced by an October contract in 1997. The November contract is the highest volume contract for canola. The November/October contract shares the title for highest volume contract with December.

drawbacks, including that it does not change over time and does not depend on the underlying past or present data.

Two other methods have been selected to estimate the hedge ratio – OLS and GARCH. These two methods calculate the minimum-variance hedge ratio which is equal to the covariance of the cash and futures returns divided by the variance of the futures returns (Coakley, Dollery, & Kellard 2008). The minimum-variance hedge ratio is found in equation (1).

$$\text{Minimum Variance Hedge Ratio} = \frac{Cov(\Delta c_t, \Delta f_t)}{Var(\Delta f_t)} \quad (1)$$

The OLS method calculates the minimum-variance hedge ratio by estimating the regression found in equation (2) using OLS (Coakley, Dollery, and Kellard 2008).

$$\Delta c_t = \beta_0 + \beta_1 \Delta f_t + \varepsilon_t \quad (2)$$

The estimated value of β_1 is equivalent to equation (1), the minimum-variance hedge ratio. This method of calculating the hedge ratio is appealing due to its simplicity and minimal transactions costs but has several drawbacks, one being that the hedge ratio does not change over time. For this paper the OLS hedge ratio is calculated in RATS specifying robust standard errors in the OLS estimation.

The GARCH(p,q) method developed by Bollerslev (1986) calculates the minimum variance hedge ratio by estimating the equations (3) to (5) for the cash and futures returns.

$$r_t = \mu + \varepsilon_t \quad (3)$$

$$\varepsilon_t = z_t \sigma_t \quad (4)$$

$$\varphi_t^2 = \omega + \sum_i^q \alpha_i \varepsilon_{t-i}^2 + \sum_j^p \beta_j \varphi_{t-j}^2 \quad (5)$$

There are many specifications of the GARCH(p,q) model. The specification of interest is the FIAPARCH(p,d,q) specification developed by Tse (1998). This specification incorporates long memory as well as leverage effects into the hedge ratio. The conditional variance of the FIAPARCH(p,d,q) specification is found in equation (6). By changing the values of various coefficients the FIAPARCH(p,d,q) specification reduces to several other GARCH(p,q) specifications. In the case where δ = 2, γ = 0, and 0 < d < 1 the FIAPARCH(p,d,q) specification can be reduced to the FIGARCH(p,d,q) specification developed by Baillie, Bollerslev, and Mikkelsen (1996) found in equation (7). If d = 0 the FIAPARCH(p,d,q) specification can be reduced to the APARCH(p,q) specification developed by Ding, Granger, and Engle (1993) found in equation (8). Lastly, if δ = 2, γ = 0, and 0 < d < 1 the GARCH(p,q) model found in equation (5) results.

$$\varphi_t^{\delta} = \omega + \left(1 - \frac{\phi(L)(1-L)^d}{1-\beta(L)}\right)(|\varepsilon_t| - \gamma\varepsilon_t)^{\delta} \tag{6}$$

$$\varphi_t^{2} = \omega + \left(1 - \frac{\phi(L)(1-L)^d}{1-\beta(L)}\right)(\varepsilon_t)^{2} \tag{7}$$

$$\varphi_t^{\delta} = \omega + \left(1 - \frac{\phi(L)(1-L)^d}{1-\beta(L)}\right)(|\varepsilon_t| - \gamma\varepsilon_t)^{\delta} \tag{8}$$

The GARCH method of calculating the hedge ratio is appealing because it incorporates the most up to date data (up to and including t-1) which is achieved by the constant revision of the hedge ratio as denoted by subscript t. One drawback of the GARCH method is the transactions costs associated with the continual revision of the position.

DATA DESCRIPTION

Fourteen crop years of futures data commencing August 1993 have been extracted from the Commodity Research Bureau Database using the PowerGen Synthetic Data Generator for each commodity. In order to form a continuous time series for the futures data a decision needs to be made about when to roll from one contract to the next. In practice, a position holder decides to roll based on liquidity and the price spread between contracts[12]. For the purpose of this study, the futures price series was generated using the closing price for the most active nearby futures contract based on volume traded with a rollover at or before the 15th day of the month prior to expiry[13]. All of the price data is for No. 1 grade and is back-adjusted. The corresponding daily cash data was provided by ICE[14]. In total, there are 3,751 observations for western barley and 3,737 observations for canola, of which 251 fall in the 2007 crop year. The most recent crop year with complete data, August 1 of 2007 through July 31 of 2008, is treated as out-of-sample data and is used to test the effectiveness and affordability of the various hedging methods being tested. Hence, observations between August 1 of 2007 and July 31 of 2008 are excluded from unit root and stationarity tests since the data would not have been available at the time the hedging strategy was being decided. In all cases, the logarithmic transformation has been made to the data prior to conducting any empirical tests or estimation and henceforth will be referred to as the price series. The logarithmic transformation has been made so that returns can be calculated as the logged difference when estimating the OLS and GARCH hedge ratios.

This section provides a brief explanation and the results of the empirical methodology used to determine whether the price series are stationary, first difference stationary, fractionally integrated and/or cointegrated. This step is required to determine the appropriate GARCH model. For example, if both the cash and the futures price series are found to be I(1) but are not cointegrated any bivariate GARCH model is appropriate. If the price series are cointegrated the

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[12] A long position holder will want to roll when the front month is priced as high as possible relative to the back month (ie., the spread is “narrow”) and a short position holder will want the back month to be priced relatively higher (i.e., the spread is “wide”) to maximize roll gain.
[13] This choice of roll over is also used by Jin and Frechette (2004).
[14] The CRB database was not used for the cash price series because the prices are late-dated. The late-dated series is a result of elevator bids being reported one day late and the transmission of the price being transmitted the following morning.

lagged cointegrating residuals must be added to the model. If the volatility of the returns are found to be fractionally integrated an appropriate GARCH model is the FIGARCH model developed by Baillie, Bollerslev, and Mikkelsen (1996) or the FIAPARCH model developed by Tse (1998).

Two standard tests were selected to evaluate the stationarity of the (logged) price series; the Augmented Dickey Fuller (ADF) test (Dickey and Fuller 1979, 1981) and the KPSS tests (Kwiatkowski et al 1992). Both of the ADF and KPSS tests were estimated with a constant and trend and a constant but no trend. The tests were performed using the 1993 – 2006 data series for canola and the 1993 – 2006 and 2002 – 2006 data series for western barley. Two different data series were used for western barley because the correlation between the cash and futures price series dramatically increased in the latter part of the 1993 – 2006 price series, thus the performance of the hedge models may vary between the two data periods. This was not the case for the canola price series. When a price series was found to be I(1) the same test was performed on the differenced price series to determine whether the price series is first difference stationary. Three methods were used to determine the optimal lag length: the minimization of the Akaike Information Criterion (AIC), the minimization of the Schwarz Bayesian Information Criterion (BIC) and the reduction method (RDTN), which starts at the maximum number of lags and reduces them one until the last lag included is significant. The maximum lag length for the ADF test was calculated by rounding up the cube root of the sample size (T) and the maximum lag length for the KPSS test is found by rounding up $t = 12\left(\frac{T}{100}\right)^{1/4}$ (Kwiatkowski, Phillips, Schmidt, and Shin 1992).

The unit root and the stationarity test were used jointly to test the null hypothesis of a unit root thus the critical values for the test statistic should be modified (Carrio-i-Silvestre, Sanso-i-

Rossello, and Ortuno 2001). The modification restricts the probability of a type II error to equal the probability of a type I error for the unit root and stationarity test. The critical values are generated using ARMA(1,1) model for samples with up to 300 observations. The generated critical values better characterize the stochastic process in the presence of a unit root. The critical values for such as large sample size are not provided by Carrion-i-Silvestre et al (2001) and will be left as a future exercise because evidence in favour of a unit root is strong for both the cash and futures price series for canola and western barley. Results are found in Table 1 and Table 2.

Based on the ADF and KPSS test results for the 1993-2006 sample, one cannot reject the null that the log(cash) and log(futures) price series for both data series are difference stationary because the unit root and stationarity tests agree at both levels of significance ($\alpha = 0.1$ and 0.05) and the conclusion for log(cash/futures) and Δlog(cash/futures) conflict in all cases. For the 2002-2006 sample for western barley log(futures) prices series the same finding holds; however the KPSS test for the cash series rejects the null hypothesis of stationarity for both the level and the differenced series indicating that the series may be fractionally integrated. The finding that the 1993-2006 cash and futures price series for canola and western barley and the 2002-2006 futures price series for western barley are difference stationary agrees with findings by Sephton (1993 and 1998) for the 1988 crop year and with Brockman and Tse (1995) for the fiscal years between 1978 and 1984. Many other agricultural commodities have been found to be difference stationary: wheat (Yang, Blessler, and Leatham 2001) (Covey and Bessler 1995), corn (Yang, Blessler, and Leatham 2001) (Zapata and Fortenbery 1996), feed cattle (Yang, Blessler, and Leatham 2001), live cattle (Yang, Blessler, and Leatham 2001) (Covey and Bessler 1995), and lean hogs (Yang, Blessler, and Leatham 2001). The finding that the futures price series for western barley may be fractionally integrated has not been reported in any previous studies.

Table 1. ADF Test for unit root

		Western Barley Crop Years 1993-2006 (Inclusive)				Canola Crop Years 1993-2006 (Inclusive)			
		log(C)	Δlog(C)	log(F)	Δlog(F)	log(C)	Δlog(C)	log(F)	Δlog(F)
C	AIC	-2.297	-11.891*,**	-1.963	-20.422*,**	-2.108	-33.258*,**	-2.155	-41.643*,**
	BIC	-1.469	-65.315*,**	-1.707	-57.012*,**	-2.011	-56.445*,**	-2.056	-55.861*,**
	RDTN	-2.203	-12.458*,**	-2.131	-13.763*,**	-2.237	-18.503*,**	-2.155	-18.655*,**
C&T	AIC	-2.329	-11.888*,**	-2.113	-20.419*,**	-2.326	-33.254*,**	-2.655	-41.638*,**
	BIC	-1.504	-65.305*,**	-1.828	-57.004*,**	-2.211	-56.437*,**	-2.496	-55.854*,**
	RDTN	-2.242	-12.455*,**	-2.328	-13.761*,**	-2.492	-18.501*,**	-2.655	-18.654*,**

		Western Barley Crop Years 2002-2006 (Inclusive)			
		log(C)	Δlog(C)	log(F)	Δlog(F)
C	AIC	-1.252	-7.533*,**	-1.515	-34.070*,**
	BIC	-1.252	-13.835*,**	-1.515	-34.070*,**
	RDTN	-1.474	-8.747*,**	-1.515	-34.070*,**
C&T	AIC	-0.831	-7.750*,**	-1.515	-34.070*,**
	BIC	-0.831	-14.056*,**	-1.515	-34.070*,**
	RDTN	-1.023	-8.999*,**	-1.515	-34.070*,**

Significance at $\alpha = 0.01$ and 0.05 denoted by *and ** respectively
C – constant C&T – constant and trend

Table 2. KPSS test for Stationarity

		Western Barley Crop Years 1993-2006 (Inclusive)				Canola Crop Years 1993-2006 (Inclusive)			
		log(C)	Δlog(C)	log(F)	Δlog(F)	log(C)	Δlog(C)	log(F)	Δlog(F)
C	Lags=0	27.278*,**	0.154	82.543*,**	0.128	83.534*,**	0.094	111.674*,**	0.118
	Lags=15	1.727*,**	0.128	5.217*,**	0.103	5.296*,**	0.084	7.069*,**	0.103
	Lags=30	0.905*,**	0.100	2.727*,**	0.090	2.773*,**	0.085	3.698*,**	0.098
C&T	Lags=0	14.104*,**	0.153	16.574*,**	0.128	13.399*,**	0.093	11.664*,**	0.116
	Lags=15	0.892*,**	0.127	1.053*,**	0.103	0.855*,**	0.084	0.745*,**	0.101
	Lags=30	0.467*,**	0.099	0.553*,**	0.091	0.451*,**	0.084	0.394*,**	0.097

		Western Barley Crop Years 2002-2006 (Inclusive)			
		log(C)	Δlog(C)	log(F)	Δlog(F)
C	Lags=0	27.490*,**	1.325*,**	24.644*,**	0.368
	Lags=15	2.529*,**	0.767*,**	2.285*,**	0.298
	Lags=30	1.181*,**	0.567**	1.078*,**	0.263
C&T	Lags=0	23.312*,**	0.119	20.406*,**	0.046
	Lags=15	2.147*,**	0.073	1.894*,**	0.038
	Lags=30	1.004*,**	0.056	0.895*,**	0.034

Significance at $\alpha = 0.01$ and 0.05 denoted by *and ** respectively
C – constant C&T – constant and trend

The standard Engle-Granger test for cointegration was selected to evaluate whether cash and futures prices are cointegrated (Engle and Granger 1987). If the cash and futures price series was found to be I(d), the series were considered to be cointegrated if ε is I(d-1). The Engle-Granger test was performed using the 1993-2006 data series for both commodities since both the cash and futures prices were found to be integrated of the same order. The test was not performed for the 2002-2006 data series for western barley because the cash and futures price series were not found to be integrated of the same order, thus are not cointegrated by definition. The Engle-Granger test for cointegration was estimated twice for each commodity. The first estimation used the cash price as the dependent variable in the cointegrating regressions and the second estimation used the futures price as the dependent variable. Three methods were used to determine the optimal lag length: AIC, BIC, and RDTN from a maximum lag length equal to the cube root of the sample size. The critical values follow that of MacKinnon (1991). Results are found in Table 3. As mentioned previously, if the cash and futures price series are cointegrated the lagged cointegrating residuals must be added into the GARCH model.

Table 3. Engle-Granger test for cointegration

		Western Barley Crop Years 1993-2006 (Inclusive)		Canola Crop Years 1993-2006 (Inclusive)	
		Dependent = log(C)	Dependent = log(F)	Dependent = log(C)	Dependent = log(F)
C	AIC	-2.068	-2194	-4549*,**	-4.053*,**
	BIC	-2.034	-2.233	-4.443*,**	-4.418*,**
	RDTN	-2.314	-2.194	-4.094*,**	-4.053*,**
C&T	AIC	-3.282	-3.426	-4.599*,**	-4.707*,**
	BIC	-3.144	-3.491	-4.939*,**	-5.026*,**
	RDTN	-3.581	-3.426	-4.599*,**	-4.707*,**

Significance at $\alpha = 0.01$ and 0.05denoted by * and ** respectively
NC – no constant C&T – constant and trend

The Engle-Granger test for cointegration revealed that the null hypothesis of no cointegration could not be rejected for the western barley price series at an $\alpha = 0.05$ and 0.01 level of significance for the 1993-2006 data series. The null hypothesis of no cointegration was rejected at both an $\alpha = 0.05$ and 0.01 level of significance for the canola price series. In each case, the same conclusion was made whether log(cash) or log(futures) was used the dependent variable. These findings indicate that the lagged residual from the cointegrating regressions should be incorporated into the canola hedging model but not the western barley hedging model.

The finding that the canola price series are cointegrated agrees with findings from the fiscal years between 1978 and 1994 by Brockman and Tse (1995) but does not agree with findings from the 1988 crop year by Sephton (1998). Conversely, the finding that the null hypothesis of no cointegration cannot be rejected for the western barley price series agrees with findings from Sephton (1998) but does not agree with findings from Brockman and Tse (1995). Findings from previous literature on cointegration between cash and futures prices indicate that there is no clear consensus on whether or not commodity prices should be cointegrated. This can be seen by the fact that cash and futures price series were found to be cointegrated for wheat (Yang, Blessler, and Leatham, 2001), corn (Yang, Blessler, and Leatham 2001) (Zapata and Fortenbery 1996), feeder cattle (Yang, Blessler, and Leatham 2001), live cattle (Yang, Blessler, and Leatha, 2001), and lean hogs (Yang, Blessler, and Leatham 2001) while the cash and futures price series were not found to be cointegrated for wheat (Covey and Bessler 1995), feeder cattle (Covey and Bessler 1995), live cattle (Bessler and Covey 1991), and lean hogs (Schreoder and Goodwin 1991).

The findings of the ADF and KPSS tests indicate that the log price series are difference stationary for all series except the western barley cash price for the 2002-2006 price series. By ignoring the exception, this indicates that the returns (ie., the differenced log price series) are stationary. Ordinarily, additional tests for fractional integration would not be necessary however, one of the main purposes of the paper is to test whether the cash and futures price return[15] and volatility[16] are fractionally integrated, thus fractional integration will be formally tested using the local Whittle estimator (Kuensch 1987, Robinson 1995), the exact local Whittle estimator (Shimotsu and Phillips 2004, Shimotsu 2004) using Matlab code by Shimotsu (2003), and the

[15] The price return is calculated as $\Delta\log(C)$ or $\Delta\log(F)$.
[16] The price volatility is calculated as $[\Delta\log(C)]^2$ or $[\Delta\log(F)]^2$ following Jin and Frechette (2004).

Geweke and Porter-Hudak (GPH) method for all data series, not just the western barley cash price for the 2002-2006 price series.

The results found in Table 4 provide evidence that the Δlog(C) and Δlog(F) price series for canola are indeed I(0) meaning that the two series are stationary and may have short-term memory (shocks die out at a geometric or exponential rate) however, this is not the case for western barley. Both Δlog(C) and Δlog(F) for western barley are fractionally integrated with $0<\hat{d}<5$ indicating the two series are stationary, invertible and may have long-term memory (shocks die out at a slow hyperbolic rate). The result for Δlog(C) and Δlog(F) for canola as well as Δlog(F) for western barley agree with findings by Crato and Ray (2000) who found cash and futures returns to be stationary (i.e., $\hat{d} = 0$) for various agricultural commodities traded on the CBOT, CME, NYCE and NYMEX. These findings indicate that the long memory in price returns should be incorporated into the hedging model for western barley, but not for canola.

Table 4. Fractional integration of cash and futures returns

	Western Barley Crop Years 1993-2006 (Inclusive)		Canola Crop Years 1993-2006 (Inclusive)	
	Δlog(C)	Δlog(F)	Δlog(C)	Δlog(F)
Local Whittle Estimator	$\hat{d}$ = 0.205	$\hat{d}$ = .093	$\hat{d}$ = 0.017	$\hat{d}$ = 0.057
Exact Local Whittle Estimator	$\hat{d}$ = 0.201	$\hat{d}$ = 0.096	$\hat{d}$ = 0.016	$\hat{d}$ = 0.056
Geweke and Porter-Hudak (GPH)	$\hat{d}$ = 0.248 OLS s.e. = 0.094 Asymp s.e. = 0.117	$\hat{d}$ = 0.146 OLS s.e. = 0.094 Asymp s.e. = 0.094	$\hat{d}$ = 0.074 OLS s.e. = 0.124 Asymp s.e. = 0.094	$\hat{d}$ = 0.088 OLS s.e. = 0.102 Asymp s.e. = 0.094

	Western Barley Crop Years 1993-2006 (Inclusive)	
	Δlog(C)	Δlog(F)
Local Whittle Estimator	$\hat{d}$ =0.224	$\hat{d}$ = 0.101
Exact Local Whittle Estimator	$\hat{d}$ =0.230	$\hat{d}$ = 0.102
Geweke and Porter-Hudak (GPH)	$\hat{d}$ =0.379 OLS s.e. = 0.140 Asymp s.e. = 0.127	$\hat{d}$ = 0.241 OLS s.e. = 0.136 Asymp s.e. = 0.127

The results found in Table 5 indicate that $[\Delta\log(C)]^2$ and $[\Delta\log(F)]^2$ for canola and $[\Delta\log(F)]^2$ for western barley are fractionally integrated with $0 < \hat{d} < 0.5$ indicating the series are stationary, invertible and may have long-term memory. The result for $[\Delta\log(F)]^2$ for western barley indicate that $0 \leq \hat{d} < 0.5$ thus the series may have short or long-term memory. Past studies on fractional integration in agricultural price volatilities have found the order of integration to be $0.2 < \widehat{d} < 0.5$ (Crato and Ray 2000), $0.3 < \widehat{d} < 0.6$ (Jin and Frechette 2004), and $0.2 < \widehat{d} < 0.6$ (Sephton 2009) for cash and futures returns. The order of integration for $[\Delta\log(F)]^2$ for western barley fell below each of the estimates. The order of integration for the remaining series fell within the range estimated by Crato and Ray (2000) and Sephton (2009). Only $[\Delta\log(C)]^2$ for canola fell within the range estimated by Jin and Frechett (2004). This finding indicates that shocks die out more quickly for the Canadian agricultural commodities traded on ICE Canada that for the agricultural commodities traded on CBOT, CME, KCBOT, and NYBOT. These findings indicate that long memory in price volatility should be incorporated into the hedging model for both commodities.

Table 5. Fractional integration of cash and futures price volatility

	Western Barley Crop Years 1993-2006 (Inclusive)		Canola Crop Years 1993-2006 (Inclusive)	
	$[\Delta\log(C)]^2$	$[\Delta\log(C)]^2$	$[\Delta\log(F)]^2$	
Local Whittle Estimator	$\hat{d} = 0.278$	$\widehat{d} = 0.346$	$\hat{d} = 0.206$	$\hat{d} = 0.206$
Exact Local Whittle Estimator	$\hat{d} = 0.285$	$\hat{d} = 0.360$	$\hat{d} = 0.204$	$\hat{d} = 0.204$
Geweke and Porter-Hudak (GPH)	$\hat{d} = 0.086$ OLS s.e. = 0.094 Asymp s.e. = 0.088	$\hat{d} = 0.218$ OLS s.e. = 0.094 Asymp s.e. = 0.123	$\hat{d} = 0.239$ OLS s.e. = 0.094 Asymp s.e. = 0.089	$\hat{d} = 0.239$ OLS s.e. = 0.094 Asymp s.e. = 0.089

	Western Barley Crop Years 2002-2006 (Inclusive)	
	$[\Delta\log(C)]^2$	$[\Delta\log(F)]^2$
Local Whittle Estimator	$\hat{d} = 0.224$	$\hat{d} = 0.101$
Exact Local Whittle Estimator	$\hat{d} = 0.230$	$\hat{d} = 0.102$
Geweke and Porter-Hudak (GPH)	$\hat{d} = 0.370$ OLS s.e. = 0.093 Asymp s.e. = 0.127	$\hat{d} = 0.024$ OLS s.e. = 0.063 Asymp s.e. = 0.127

HEDGE RATIO ESTIMATION AND EFFECTIVENESS

This section estimates the ratio for each of the three hedging strategies and compares their effectiveness both within the sample and outside the sample (2007 crop year). The OLS and FIAPARCH hedge ratios are calculated the crop years between 1993 and 2006 (inclusive) for canola and western barley as well as for the crop years between 2002 and 2006 (inclusive) for western barley. The measure of hedging effectiveness selected to compare the hedging models is the variance reduction. The variance reduction compares the variance of the unhedged portfolio with the variance of the hedged portfolio. The hedged portfolio is defined as $\Delta c_t - \gamma \Delta f_t$ for the naive and OLS hedge ratios and as $\Delta c_t - \gamma_t \Delta f_t$ for the GARCH hedge ratio where γ_t denotes the hedge ratio at time t. The variance reduction is calculated as $\left(1 - \frac{Var_H}{Var_U}\right) \times 100$ which gives the percentage reduction in variance. A hedge will be considered more efficient if it has a higher reduction in variance (in percent), with a maximum value of 100%.

The first of the three hedging strategies, the 1:1 hedge, does not require any calculations. The ratio is always one. The ratio for the OLS hedging strategy is calculated using equation (1) which is calculated by estimating equation (2) from the hedging strategy section. The hedge ratio estimates are found in Table 6.

Table 6. OLS hedge ratio

	Western Barley		Canola
	Crop Years 1993 - 2006	Crop Years 2002 - 2006	Crop Years 1993 - 2006
Hedge Ratio	0.200	-0.000	0.914
Standard Error	0.031	0.032	0.040

The various tests performed in the data description section provide a starting point for the selection of the hedging model. One of the most important findings is that the spot and futures price volatility for Canadian agricultural futures are fractionally integrated. Given this information, the FIAPARCH model is used to estimate the hedge ratio for canola and western barley. The fractional integration in the returns for western barley indicate that ARFIMA should be incorporated into the conditional mean, however ARMA should suffice for canola. Lastly, the cointegration between the cash and futures prices for canola indicate that the lagged cointegrating residuals should be incorporated into the mean equation of the FIAPARCH models. The model specification was selected based on the statistical significance of individual estimated parameters and the overall hedging significance. The FIAPARCH model was reduced to the FIGARCH, APARCH, or GARCH model based on statistical significance of specific estimated parameters (see equations 5 through 8). All models were estimated using both gauss and student-t distributed error terms. The GARCH hedge ratio is calculated using G@RCH 5.0 within OX 5.0. The parameter estimates for the best within sample FIAPARCH/GARCH models are found in Table 7 and graphs of the FIAPARCH/GARCH hedge ratios are found in Figure 1.

Table 7. FIAPARCH/GARCH within sample models

		1993 - 2006		2002 - 2006	
		Dependent = Cash	Dependent = Futures	Dependent = Cash	Dependent = Futures
		ARFIMA(1,d,1) FIAPARCH(1,d,1)		ARFIMA(1,d,1) GARCH(1,1)	
Western Barley	Constant in mean	0.000 t = 0.115	0.000 t = 0.600	-0.000 t = -0.010	0.000 t =-0.406
	Constant in variance	1.076 t = 1.230	0.020 t = 0.154	0.026 t = 0.020	0.005 t = 0.375
	AR(1)	-0.051 t =-0.715	0.614 t = 9.920	0.003 t = 0.980	-0.960 t = -2.303
	MA(1)	-0.288 t =-2.830	-0.743 t = -12.160	-0.225 t =-1.408	0.955 t = 0.060
	d-ARFIMA	0.208 t = 4.384	0.167 t = 0.445	0.222 t = 3.155	0.052 t = 1.131
	ARCH(ϕ)	0.261 t = 3.714	0.422 t = 1.555	0.078 t = 3.023	0.011 t = 1.160
	GARCH(β)	0.711 t = 6.718	0.488 t = 1.310	0.891 t =28.33	0.989 t = 339.3
	d-FIGARCH	0.542 t = 0.000	0.112 t = 0.657		
	APARCH(γ)	-0.105 t =-1.640	-0.482 t = -1.200		
	APARCH(δ)	2.060 t = 14.40	2.490 t = 2.290		
		ARMA(1,1) FIAPARCH(2,d,1)			
Canola	Constant in mean	0.000 t = 0.009	0.000 t = 0.453		
	Constant in variance	4.756 t = 1.340	1.563 t = 1.118		
	ECM Cash	-0.032 t =-1.704	-0.039 t =-1.781		
	ECM Futures	-0.033 t =-1.897	-0.040 t =-2.061		
	AR(1)	-0.400 t =-2.721	-0.304 t =-2.612		
	MA(1)	0.451 t = 3.186	0.371 t = 3.301		
	ARCH(ϕ)	0.588 t = 3.121	0.650 t = 8.327		
	GARCH(β_1)	0.839 t = 3.776	0.962 t = 8.136		
	GARCH(β_2)	-0.098 t = -1.283	-0.127 t =-2.188		
	d-FIGARCH	0.361 t = 4.524	0.387 t = 4.050		
	APARCH(γ)	0.040 t = 0.442	-0.254 t = -1.511		
	APARCH(δ)	1.827 t = 13.27	1.927 t = 13.55		

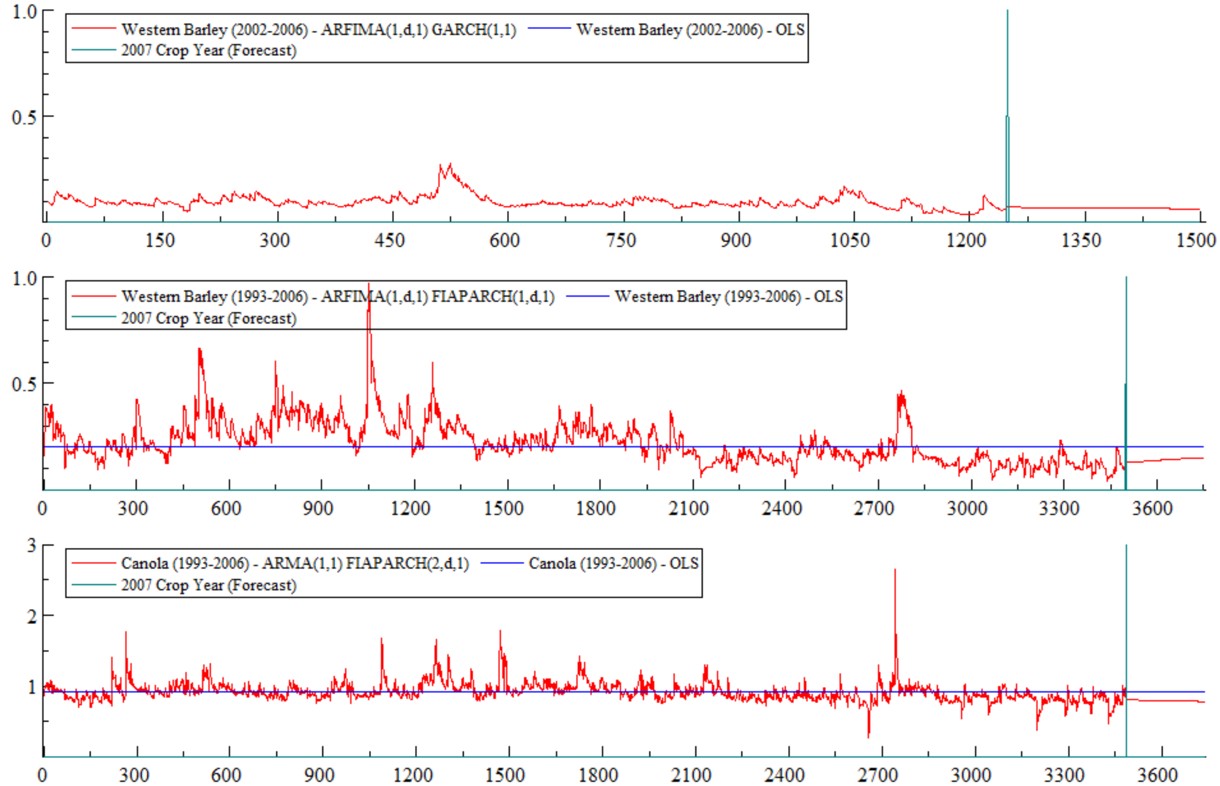

Figure 1. FIAPARCH/GARCH and OLS hedge ratios

Note: The crop years between 1993 and 2006 precede the vertical grey line. The 2007 crop year includes all data points to the right of the vertical grey line

The efficiency, as measured by the percentage reduction in variance, for each hedging model is found in Table 8. The efficiency is provided for within the sample and for the 2007 crop year. The efficiency of the 2007 crop year is calculated by forecasting the hedging model by 251 days (the number of trading days in the 2007 crop year) using all of the data up to and including July 31 of 2007.

Table 8. Reduction in Portfolio Variance (in comparison to no hedging)

	Western Barley		Canola	
	Within Sample	2007 Crop Year	Within Sample	2007 Crop Year
1:1 (1993-2006)	-60.17%	-147.37%	71.74%	90.50%
OLS (1993–2006)	4.24%	-0.66%	72.46%	90.50%
FIAPARCH (1993-2006)	5.08	1.32%	71.74%	88.13%
FIAPARCH (2002-2006)	-89.66%	1.32%	N/A	N/A

Overall, the hedging effectiveness of all three methods performed better for canola than western barley. The FIAPARCH model using the 1993-2006 data series performed the best for western barley for both within and without the sample. It is worth pointing out the negative reduction in portfolio variance for the 1:1 method using the 1993-2006 data series and the FIAPARCH model using the 2002-2006 data series. This means that a producer would have increased his or her portfolio variance if he or she had chosen one of these hedging methods. The hedging effectiveness for each method considered was poor and most likely would not be considered an effective means to reduce western barley price risk. A potential cause of the poor performance may be the low trading volume nearing the end of the data series. Also, the recent attempt by the federal government to remove the single desk marketing of western barley and the various court cases and appeals surrounding that attempt may have negatively impacted the performance in the later part of both data series. The ICE has modified the contract specifications for western barley to ease the delivery process effective in the fall of 2009. The modifications include changing the delivery region to southern Alberta, adding a barley merchant[17] to the participant category, and allowing shipment by truck only. This modification may improve the hedging efficiency, thus the hedging effectiveness should be re-evaluated in the future. The OLS model using the 1993-2006 data series performed the best for canola for both within and without the sample however, it only performed 2.3 percent better than the FIAPARCH model. Even though the OLS and 1:1 hedge ratio outperformed the FIAPARCH model, a producer may still chose to hedge based on the FIAPARCH model to avoid jump risk. The hedging models performed well for each method considered, leading to the conclusion that hedging price risk using ICE futures contracts is an effective means to reduce canola price risk.

[17] Barley Merchant participants are permitted to make delivery. Previously, one had to be a Merchant Multi-Commodity in order to make delivery.

HEDGING AFFORDIBILITY

This section determines whether hedging price risk using the ICE futures contracts is an affordable price risk management strategy for Canadian commodity producers. The scenario outlined in the hedging strategy section is used to assess the affordability of each hedging strategy. To summarize, a producer sells short 9 futures contracts multiplied by the hedge ratio for the fall delivery month on the first of July and buys them back once the crop has been harvested so that, if necessary, he or she is able to deliver against the futures contract. It is assumed that the producer exits the short position on the first of October. The affordability of each hedging strategy is evaluated by comparing the cost of hedging with the cost of production associated with each crop (excluding all costs associated with managing price risk).

Affordability is assessed for the most effective (within sample) strategy, thus the FIAPARCH model using the 1993-2006 data series is used for western barley and the OLS hedge ratio is used for canola. Only the most effective (within sample) strategy has been analysed because a producer hoping to reduce price risk would most likely select the most effective strategy. The hedging positions for the FIAPARCH hedge ratio are updated on the Wednesday of each week, allowing the most up to date data to be incorporated in order to achieve an accurate hedge ratio. The ratios are updated weekly because it is not realistic for producers to trade futures contracts every day. Wednesday is selected so that the producer can avoid uncertainty associated with opening on Monday, closing on Friday, and long weekends. The number of contracts that a producer should short sell is calculated by multiplying the hedge ratio by nine. Since a producer is not able to trade a portion of a contract the number of contracts is rounded up for decimals greater than five tenths and rounded down otherwise. The hedge positions for western barley and canola are found in Figure 2.

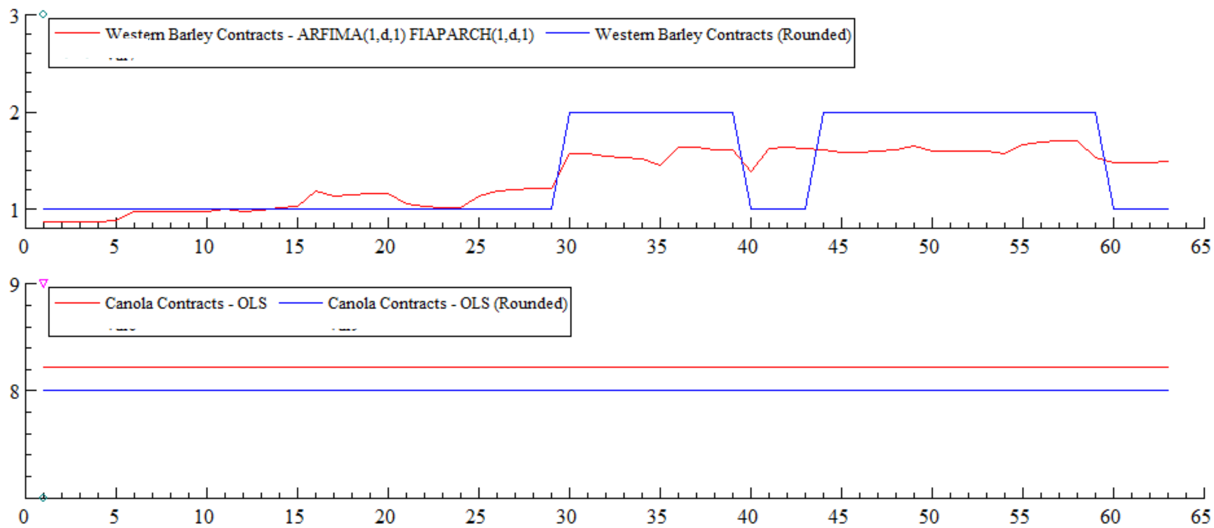

Figure 2: Weekly hedge positions for canola and western barley from July to October of 2008

The cost of hedging using futures contracts is calculated by summing the transactions cost and the opportunity cost associated with providing margin money. The transaction cost associated with trading one ICE Futures Canada contract is $1.50. The margin requirement for one canola contract is 250 dollars with a 250 dollar maintenance and the margin requirement for one western barley contract is 170 dollars with a 170 dollar maintenance[18]. The opportunity cost of the required margin money is calculated using the daily Bank of Canada bank rate plus 1.5 percent to approximate the interest rate for an operating loan[19]. The total cost of hedging using futures contracts is compared to the total operating cost per tonne, which is $305 and $114 for canola and western barley respectively for the province of Manitoba[20] (Manitoba Agriculture and Rural Initiatives 2009). The cost of each hedging strategy is found in Table 9.

[18] Effective July 9, 2009 margins increased to 300 dollars for canola and decreased to 150 dollars for western barley.
[19] It is assumed that margin money is financed by operating loans, which is the standard practice. In the case of an increasing futures price lenders are often leery to extend operating loans. From a producer's perspective, this is a very real risk associated with managing price risk using futures contracts.
[20] It is assumed that the operating costs in the province of Manitoba represent western Canada, which accounts for 90 percent of the western barley and 98 percent of the canola produced in Canada.

Table 9. Total cost associated with hedging western barley and canola		
	Western Barley	Canola
	ARFIMA(1,d,1) APARCH(1,d,1)	OLS
Total Transaction Cost	$9.00	$24.00
Total Interest on Margin Money	$3.05	$26.03
Total Cost	**$12.05**	**$50.01**
Total Cost per Tonne	$0.06	$0.28
% of Total Operating Cost[21]	0.06%	0.09%

The cost associated with hedging price risk using ICE futures is only a fraction of a percent of the total operating cost associated with production for the 2007 crop year scenario. Several reasons for the low cost include minimal margin requirements due to the steady decline in futures price between the first of July and the first of October, low interest rates, and the short time horizon. Additionally, the relatively stable FIAPRCH hedge ratio minimized transactions costs for western barley. Overall, it is hard to dispute that hedging canola and western barley price risk using ICE futures is not affordable.

CONCLUDING REMARKS

This paper adds to the understanding of managing market price risk for canola and western barley using the Canadian based futures contracts offered by ICE Futures Canada in several ways. First, it finds long-memory to be present in the returns for western barley and the volatilities for both canola and western barley. Second, it estimates several variations of the GARCH hedge ratios, finding the FIAPARCH hedge ratio to be the most effective. This indicates that long-memory has a role in hedging effectiveness for Canadian traded commodities. The FIAPARCH hedge ratio is found to outperform the 1:1 and OLS hedge ratio for western barley, however the OLS hedge ratio is found to outperform the FIAPRCH hedge ratio for canola. In both cases, the FIAPARCH and OLS hedge ratios perform similarly. Overall, the

[21] Operating costs include seed and treatment, fertilizer, herbicide, fungicide, insecticide, fuel, machinery operating, crop insurance, land taxes, drying costs, interest on operating loan and other costs.

hedging effectiveness of all three methods performed better for canola than western barley, with maximum portfolio variance reduction for the 2007 crop year being 90.5 and 1.32 percent respectively. Third, this paper finds hedging ratios estimated using long periods of data (2002-2006) to outperform those estimated with short periods of data (2002-2006).

The findings of this paper indicate that the ICE futures contract for canola is an effective and affordable means of reducing price risk management for canola producers and should be considered as part of a price risk management strategy. On the other hand, the findings indicate that the ICE futures contract for western barley is not as effective as a means of reducing price risk for western barley producers, however it is affordable. At the current time, western barley producers should consider alternative means of price risk management, however the ICE futures contract should be reconsidered after modifications to contract specifications come into effect.

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REFERENCES

Agriculture and Agri-food Canada. 2007. Barley Production in Canada – Fact Sheet. March 2007. Retrieved January 23rd from http://www.agr.gc.ca/cb/ip/pdf/fact4_e.pdf.

Amoroso, X, J. Unterschultz, and T. Nilsson. 2009. Price risk management of canola in western Canada. AARI project number: #2006F022R.

Ballie, R., T. Bollerslev, and H. Mikkelsen. 1996. Fractionally integrated generalized autoregressive conditional heteroskedasticity. Journal of Econometrics 74(1): 3-30.

Baillie, R., and R. Myers. 1991. Bivariate GARCH estimation of the optimal comodity futures hedge. Journal of Applied Econometrics 6: 109-124.

Bessler, D. A., and Covey, T. 1991. Cointegration: Some results on U.S. cattle prices. Journal of Futures Markets 11: 461-474.

Bollerslev, T. 1986. Generalized autoregressive conditional heteroskedasticity. Journal of Econometrics 31: 5-59.

Brockman, P. And T. Yiuman. 1995. Information shares in Canadian agricultural cash and futures markets. Applied Economics Letters 2(10): 335-338.

Brunetti, C. and C. Gilbert. 2000. Bivariate FIGARCH and fractional cointegration. Journal of Empirical Finance 7: 509–530.

Bystrom, H. 2003. The hedging performance of electricity futures on the Nordic Power Exchange. Applied Economics 35: 1–11.

Canada Grains Council. 2001. 2001 statistical handbook: Including charts and CD. The Canada Grains Council, Suite 1215-220 Portage Avenue, Winnipeg, Manitoba.

Carrion-i-Silvestre, J. L., Sanso-i-Rossello, A., and Ortuno, M. A. 2001. Unit root and stationarity tests' wedding. Economics Letters 70(1): 1-8.

Coakley, J., Dollery, J., and Kellard, N. 2008. The role of long memory in medging effectiveness. Computational Statistics and Data Analysis *52:* 3075-3082.

Covey, T., and Bessler, D. 1995. Assed storability and the informational content of inter-temporal prices. Journal of Empirical Finance 2(2): 103-115.

Crato, N. And B. Ray. 2000. Memory in returns and volatilities of futures' contracts. The Journal of Futures Markets 20(6): 525-543.

Dakers, S. and J.D. Frechette. 1998. The Canadian Wheat Board. Government of Canada, Parliamentary Research Branch PRB 98-2E. Retrieved January 25th, 2009 from http://dsp-psd.pwgsc.gc.ca/Collection-R/LoPBdP/modules/prb98-2-grain/wheatboard-e.htm.

Dickey, D., and W. Fuller. 1979. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association 74: 427-421.

Dickey, D., and W. Fuller. 1981. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49(4): 1057 – 1072.

Ding, Z., C. Granger, and R. Engle. 1993. A long memory property of stock market returns and a new model. Journal of Empirical Finance 1: 83 – 106.

Engle, R and C. Granger. 1987. Cointegration adn error correction: Representation, estimation and testing. Econometrica 55:251-276.

Figuerola-Ferretti, I. and C. Gilbert. 2008. Commonality in the LME aluminum and copper volatility processes Through a FIGARCH Lens. The Journal of Futures Markets 28(10): 935–962.

Food and Agriculture Organization of the United Nations (FAO). 2009. FAOSTAT. Retrieved January 24th, 2009 from http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor.

Government of Manitoba. 2009. Barley. Retrieved January 24th, 2009 from http://www.gov.mb.ca/trade/globaltrade/agrifood/commodity/barley.html.

Geweke and Porter-Hudak. 1983. The estimation and application of long memory time series models. Journal of Time Series Analysis 4: 221-238.

Hardaker, J., R. Hurine, J. Anderson, and G. Lien. 2004. Coping with Risk in Agriculture, Second Edition. CABI Publishing, Wallingford Oxfordshire. P 6-7.

ICE. 2009. Canola futures. Retrieved January 24th, 2009 from https://www.theice.com/productguide/productDetails.action?specId=251.

Jin, H. and D. Frechette. 2004. Fractional integration in agricultural futures price volatilities. American Journal of Agricultural Economics 86(2): 432–443.

Kearns, K.S. 2002. The Winnipeg Commodity Exchange. The Canadian encyclopaedia. January 1st, 2002. Retrieved November 2009 from http://www.thecanadianencyclopedia.com.

Kuensch, H. 1987. Statistical aspects of self-similar processes. In Proceedings of the First World Congress of the Bernoulli Society (Yu. Prokhorov and V.V. Sazanov, eds.) 1: 67-74. VNU Science Press, Utrecht.

Kwiatkowski, D., Phillips, P. C., Schmidt, P., and Shin, Y. 1992. Testing the null hypothesis of stationary against the alternative of a unit root. Journal of Econometrics 54: 159-178.

Lien, D., Y. Tse and A. Tsui. 2002. Evaluating the hedging performance of the constant-correlation GARCH model. Applied Financial Economics 12: 791–798.

MacKinnon, J. G. 1991. Critical values for cointegration tests. In R. E. Engle, & C. W. Granger, *Long-Run Economic Relationships* (pp. 267-274). Oxford University Press.

Manitoba Agriculture, Food and Rural Initiatives. 2009. Guidelines for estimating crop production costs – 2009. Retrieved July 25, 2009 from http://www.gov.mb.ca/agriculture/financial/farm/software.html#cop.

Robinson, P. M. 1995. Gaussian semiparametric estimation of long range dependence. Annals of Statistics 23: 1630-1661.

Schroeder, T., and Goodwin, B. 1991. Price discovery and cointegration for live hogs. Journal of Futures Markets 11: 685-96.

Sephton, P. 1993a. Optimal hedge ratios at the Winnipeg commodity exchange. The Canadian Journal of Economics 26(1): 175-193.

Sephton, P. 1993b. Hedging wheat and canola at the Winnipeg Commodity Exchange. Applied Financial Economics 3: 67 – 72.

Sephton, P. 1998. GARCH and MARKOV hedging at the Winnipeg Commodity Exchange. Canadian Journal of Agricultural Economics 46: 117 – 126.

Sephton, P. 2009. Fractional integration in agricultural futures price volatilities revisited. Agricultural Economics 40: 103 – 111.

Shimotsu, K. 2003. Dest.m (Matlab Code). http://www.econ.queensu.ca/pub/faculty/shimotsu/ (accessed July 16, 2009).

Shimotsu, K. 2004. Exact local Whittle estimation of fractional integration with unknown mean and time trend. Mimeo. Queen's University.

Shimotsu, K. and Phillips, P. (2005). Exact local Whittle estimation of fractional integration. Annals of Statistics 33(4): 1890-1933.

Statistics Canada. 2008. Production of principal field crops. The Daily, August 22, 2008. Retrieved January 24th from http://www.statcan.gc.ca/daily-quotidien/080822/dq080822a-eng.htm.

Statistics Canada. 2009a. Exports of grains, by final destination. CANSIM II Series V126138. Retrieved January 24th, 2009.

Statistics Canada. 2009b. Table 001-0010 - Estimated areas, yield, production and average farm price of principal field crops, in metric units, annual, CANSIM (database), Using E-STAT (distributor). http://estat.statcan.gc.ca/cgi-win/cnsmcgi.exe?Lang=E&EST-Fi=EStat//CII_1-eng.htm (accessed: July 13, 2009).

The Alberta Barley Commission. 2009. Barley. Retrieved January 25th, 2009 from http://www.albertabarley.com/barley/malt/malt.html.

Tse, Y. 1998. The conditional heteroskedasticity of the Yen-dollar exchange rate. Journal of Applied Econometrics 193: 49-55.

Wilcox, D. 2007. What is a typical Manitoba crop producer? Manitoba Agricultural Services Corporation. Yield Manitoba.

Winnipeg Commodity Exchange. 2005. WCE Historical Summary. Retrieved August 7th, 2006 from http://www.wce.ca/aboutus.aspx?first=history.

Yang, J., & Awokuse, T. O. 2003. Asset storability and hedging effectiveness in commodity futures markets. Applied Economics Letters 10(8): 487-491.

Yang, J., Bessler, D. A., & Leatham, D. J. 2001. Asset storability and price discovery in commodity futures market: A New Look. The Journal of Futures Markets 21(3): 279-300.

Zapata, H. O., & Fortenbery, T. R. 1996. Stochastic interest rates and price discovery in selected commodity markets. Review of Agricultural Economics , 18(4): 643-654.