An Evaluation of Pricing Performance and Hedging Effectiveness of the Barley Futures Market

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This paper investigates the pricing efficiency and hedging effectiveness of the Winnipeg barley futures market, using the Chicago corn futures market as a norm. Several tests of pricing efficiency were conducted and the stability of the basis was studied. The barley futures market operates in a heavily regulated economic environment and this is shown to impact on both price behavior and hedging opportunities.

The behavior of commodity futures prices always has drawn attention in the economics literature and this interest extends from well-established to newly-formed markets. Studies of price behavior on futures markets have been primarily concerned with both pricing efficiency and hedging opportunities. A price efficient market can be briefly described as one in which new information concerning supply or demand is discounted accurately and rapidly into the futures price. On the other hand, hedging opportunities are a function of basis behavior.

The primary objective of this paper is to assess the pricing efficiency of the Winnipeg feed barley futures market. In addition, the effectiveness of hedging on the market is studied. Price behavior on the barley market is compared with that on the Chicago Board of Trade (CBT) corn market. The corn futures market is used as a norm because it is considered to be one of the most efficient in terms of price discovery (Gray) and it operates without many of the regulatory constraints which impinge on the barley futures market.

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Theoretical and Methodological Framework

Empirical work on efficient markets measures the adjustment of market prices to a particular information set. In his review of studies in security markets, Fama classified efficient market tests into three groups: weak, semi-strong and strong form. The information set for weak-form tests is confined to historical market prices. Semi-strong form tests measure the market's adjustment to historical prices plus all other relevant public information and strong form tests measure its adjustment to "inside" information not available to the public. This paper provides three different weak-form tests for barley and corn futures.

Structured as a weak-form analysis, a naive statistical test of the martingale hypothesis is presented first. The null hypothesis under this test is that prices (and returns) in an efficient market are normally expected to follow a martingale stochastic process throughout time (Samuelson). A martingale is a stochastic sequence of variables and its major characteristic is that the conditional expected value of the random variable for time t + 1 equals the value for time t.[1] Stevenson and Bear have applied this test to corn and soybean futures.

The second efficiency test is a test of the theory of normal backwardation, which was postulated by Keynes. In developing the theory, Keynes emphasized the financial burden posed by the necessity for carrying inventories of agricultural products and he suggested futures markets exist to facilitate hedging. He argued that futures prices are unreliable estimates of the cash or spot price prevailing on the date of expiry of the futures contract and thus it is "normal" for the futures price to be a downward-biased estimate of the forthcoming spot price. This theory, in effect, suggests that speculators sell insurance to hedgers and that the market is normally inefficient because the futures price is not an unbiased estimate of the subsequent spot price.

A major implication of the theory of normal backwardation (which assumes hedgers are continuously net short) is that a strategy of maintaining a long position in the futures market should earn positive profits over time. To test this implication in this paper, a simple theoretical trading routine was conducted with past Winnipeg barley and Chicago corn futures prices. This test was first used by Gray and it simply consists of hypothetically purchasing each futures contract on the first trading day in the delivery month of the preceding futures contract and then selling it on the first trading day of its own delivery month. This test is only valid in a nontrending market because if there is an upward trend in cash prices, the procedure may indicate a bias exists when it does not.

Cootner argued that Keynes' hypothesis implies futures prices should not necessarily rise until after the peak of net short hedging has passed and he interpreted the theory to mean seasonal trends in futures prices should be taken as an indication of a risk premium. This interpretation is also tested in this study by assuming speculators take both long and short futures positions.

The theory of normal backwardation has recently been subjected to more rigorous tests than Gray's (for example, see Dusak and Carter *et al.*). However, since the major purpose of this paper is to conduct a relative rather than an absolute analysis of efficiency, the Gray test has sufficient merit as a weak-form test.

The third test for efficiency in this paper is an examination of the forecasting ability of the barley futures market vis-a-vis the corn futures market. The springtime forecast of a post-harvest price is evaluated for a number of years by computing the mean square prediction error. Tomek and Gray, and later Kofi, were the first to test the forecasting ability of the futures market within the context of market efficiency. They challenged Working's reluctance to view futures price quotations for storable commodities as forecasts and they argued that inventories of storable commodities provide a linkage between the springtime prices of the post-harvest futures and the subsequent harvest time prices, which helps to make the futures price a self-fulfilling forecast. They estimated the coefficients of the linear regression equation: $P_h = \alpha + \beta P_{fh} + e_h$, where P_h = cash price at harvest time, P_{fh} = planting time futures quotation for harvest time contract, and e_h = error term. A "perfect forecast" was deemed one for which α and β were estimated to be zero and unity, respectively. Both studies found that the forward pricing function of futures markets was more reliable for continuous than for discontinuous inventory markets. Leuthold, Martin and Garcia, and Stein have subsequently investigated the

[1] There are exceptions to this naive rule as Danthine and Lucas have both shown theoretically that periodical failure of the martingale property to hold is not evidence of market inefficiency.

forecasting efficiency of futures markets using a similar approach of regressing cash prices on lagged futures prices.

Finally, the hedging effectiveness of barley relative to corn is investigated. One of the traditional purposes of a futures market is to provide primary producers and grain merchants an opportunity to reduce price variability through hedging. The effectiveness of hedging is estimated in this paper by regressing changes in cash prices on changes in futures prices. The results provide estimates of both the optimal (minimum-risk) hedge ratio as a proportion of the cash position and the degree to which price variance could be reduced through hedging.

Institutional Considerations

Barley futures have been traded on the Winnipeg Commodity Exchange (WCE) in one form or another almost continuously since 1912. However, from the late 1940s until 1974 the Canadian Wheat Board (CWB), a government agency, had monopoly selling privileges for all interprovincial and export sales and this severely restricted the functioning of the futures market.

The barley futures contract was later rewritten as a feed grain contract in 1974 when the Canadian government changed the feed grain policy by creating a "dual" marketing system for barley. This new structure allowed for domestic producer sales of barley either through the "open-market" commercial grain companies or through the CWB and it thus reduced the role of the CWB in the marketing of barley. Open-market transactions now dominate domestic sales and they center around the barley futures market. This policy change still did not create a truly competitive barley market, however. To date, there remain four critical regulations which restrict competitive market forces from freely operating. Firstly, the CWB continues to regulate producer delivery quotas on open-market sales (since August 1979) and thus open-market demand cannot always be satisfied. Secondly, the open-market transactions are for domestic usage only and thus there is a lack of arbitrage between the domestic and world barley markets. Thirdly, the CWB makes domestic barley sales at a regulated corn-competitive[2] price which periodically acts as a ceiling on open-market futures prices. Finally, the CWB sets "initial" barley prices each crop year and these often serve as a domestic floor price.

In contrast to the Chicago corn market, the Winnipeg barley futures market thus operates within a number of regulatory constraints, such as those mentioned above. An elaboration of the economics of these restrictions is found in Carter. The major effect of the government regulations is to inhibit the reflection of world supply and demand fundamentals for barley on the barley futures market.

Undoubtedly, the price performance and hedging opportunities on the barley market will differ from the corn market because of the differing economic environments they operate within. In a welfare assessment we might expect a priori that the Canadian regulations have both positive (e.g., price stabilizing) and negative (e.g., constrained arbitrage opportunities) impacts on the barley market participants, with the net effect being uncertain. The motivation for this paper stems from the question as to how well the barley market performs, relative to the corn market, in light of the considerable amount of institutional regulation in Canada.

[2] The corn competitive price is calculated on the basis of importing corn and soybean meal into Canada from the U.S. Corn and soybean meal prices are then converted into "equivalent" feed barley prices on the basis of digestible energy and protein content. This regulated price for barley has been in place since 1976.

TABLE 1. Serial Correlation Coefficients for First Differences between the Natural Logs of Daily Feed Grain December Futures 1977–81.

Commodity	Year	Time Lag (1–24)											
		1 13	2 14	3 15	4 16	5 17	6 18	7 19	8 20	9 21	10 22	11 23	12 24
Corn	1977	.05	−.08	.00	−.05	.05	.08	.08	−.08	−.04	.07	.03	.04
		.10	−.08	−.05	.00	.08	.05	−.01	.10	.07	−.01	.07	−.01
	1978	.02	−.09	.02	.03	.07	.00	.02	.11	−.04	.03	.02	.04
		−.01	.05	−.07	−.07	.12	.18[a]	.00	−.14[a]	−.04	−.04	−.02	−.02
	1979	−.10	.13[a]	−.04	.01	.06	−.04	.12	.01	.04	.06	−.03	−.03
		.03	−.18[a]	.03	−.09	.03	−.05	−.07	.00	.03	.05	−.13	.09
	1980	−.03	−.08	.03	.07	−.02	−.12	.12	−.08	−.07	−.02	.03	.02
		−.09	.15[a]	.02	−.04	.00	.05	−.02	−.02	.16	−.05	−.03	−.06
	1981	.03	−.06	.07	−.03	−.09	.04	.04	.03	−.11	.01	.05	−.09
		−.03	.16[a]	−.02	−.03	.05	.06	.02	−.01	.05	−.01	−.02	−.09
Barley	1977	−.04	−.14	.16[a]	−.06	−.03	−.01	.00	.04	−.02	.02	.11	.00
		−.15	.09	.06	−.10	.05	.13	.14	−.03	−.04	.06	.13	−.14
	1978	.04	−.08	−.10	−.10	.01	.08	−.07	−.02	.03	−.02	.07	.04
		−.01	−.03	.06	−.05	.12	.03	−.16[a]	.02	.04	.01	−.06	−.14
	1979	.09	−.02	−.14[a]	−.03	.01	.03	.03	−.01	.01	−.01	−.06	.04
		−.03	−.12	−.07	.00	−.09	−.13	.02	.11	.13	−.13	−.12	−.14[a]
	1980	.06	−.05	−.08	−.08	−.08	.08	.07	−.06	−.12	−.08	−.02	.02
		.07	.01	−.03	−.08	−.06	.10	−.03	.03	.06	−.10	−.12	.07
	1981	.08	−.09	.03	−.09	.00	.00	.06	−.08	.01	.04	−.02	.13
		−.08	−.02	.04	−.06	−.02	.03	.05	−.02	−.03	−.06	−.01	.05

[a] Statistically significant, i.e., difference is more than twice the standard error.

The Martingale Hypothesis

This section provides a naive weak-form test for efficiency; a test of the random walk or the more general martingale hypothesis. The results reported in Table 1 for barley and corn are based on first differences of the natural logarithms of daily closing December futures prices. The data were organized for consecutive days within a trading year and the 1977–81 period of futures market returns were analyzed. These data were obtained from the Winnipeg Commodity Exchange and Chicago Board of Trade annual statistical handbooks.

Denoting successive values of the series of commodity futures returns by R_t, R_{t+1}, . . . , R_T, one can estimate the autocorrelation function by:

$$\hat{\rho}_k = \frac{\sum_{t=1}^{T-k} (R_t - \bar{R})(R_{t+k} - \bar{R})}{\sum_{t=1}^{T} (R_t - \bar{R})^2} \qquad (1)$$

where k is the lag between observations and $\bar{R} = \frac{1}{T}\sum_{t=1}^{T} R_t$ is the sample mean.

A large and statistically significant degree of serial dependence ($\hat{\rho}_k$) would suggest that the time series R_t, R_{t+1}, . . . , R_T does not strictly follow a martingale sequence because expected changes in market returns $[E(R_t)]$ are zero if the sequence follows a martingale:

$$E[(R_{t+1} - R_t) \mid \Phi_t] = E(\epsilon_t) = 0 \qquad (2)$$

where ϕ_t is a general symbol for the relevant set of information at time t. Expression (2) states that if the returns follow a martingale model, then the expected value of a one-period change in market returns is independent of all past information and thus, for an efficient market, all of the $\hat{\rho}_k$ coefficients should be close to zero.

Table 1 presents estimates of the serial correlation coefficients ($\hat{\rho}_k$'s) for k = 1, . . . , 24 for barley and corn futures returns. There are 24 estimated coefficients for each year 1977–81. The first row for each year in Table 1 contains estimates for k = 1, . . . , 12 and the second row for k = 13, . . . , 24. For the most part the estimated coefficients are relatively small in absolute value and this suggests serial dependence is not evident in either market. We can, therefore, conclude that the barley futures market is just as efficient as the corn market based on this test.

In addition to an estimate of the randomness of returns (which appears in Table 1), it is also of interest to compare the variability of daily market returns in the Winnipeg and Chicago futures markets. It is commonly assumed that less active markets, such as barley, exhibit more price volatility than more active markets, such as corn. On the other hand, some of the Canadian regulations may result in greater price stability on the barley market because they implicitly provide price floors and ceilings from time to time.

Table 2 reports the coefficient of variation for daily December futures returns over the 1977–81 period. The coefficient of variation is the square root of the variance of the returns divided by their mean and the higher this statistic the more volatile the random variable in question. From the table we find on average the variability of returns on Chicago corn futures is higher than for barley futures. The inference is that the regulations in Canada do serve to reduce the variance of barley futures prices. Within each market the levels of variability from year to year are also very different and this makes it more difficult to generalize about price variability both within and between markets.

TABLE 2. Variability of Daily Market Returns[a] December Futures: 1977–81.

Commodity	Year	Coefficient of Variation[b]
Corn	1977	15.44
	1978	5.87
	1979	44.82
	1980	17.34
	1981	6.80
Average		18.05
Barley	1977	10.00
	1978	21.69
	1979	8.38
	1980	7.27
	1981	7.45
Average		10.96

[a] Returns were computed as the first differences between the natural logarithms of daily December futures prices.

[b] Defined as the standard deviation divided by the absolute value of the mean.

Analysis of Long-Run Market Returns: The Theory of Market Bias

The Winnipeg futures market has often been characterized as a "thin" market, which means that trading is light or, in other words, there is insufficient hedger and speculator interest in the market. Lack of sufficient trading volumes plagues many futures contracts during their growing stages. For example, in the early 1950s, the soybean contract on the Chicago Board of Trade lacked trading interest but today is one of the most highly active markets in the world.

A thin grain futures market tends to favour buyers of contracts over sellers because in such a market there is often a good deal of short selling by hedgers which does not attract a sufficient amount of long buying by speculators. The consequence of more sellers than buyers is a depressed price and thus for distant futures months

TABLE 3. Results of Routine Buying Programs in Barley and Corn Futures: 1974–81.

Commodity	Speculative Market Position	Dates of First Purchase and Last Sale	Price at Beginning and Ending Dates ($ per bushel)	Number of Trades	Average Profit Per Trade ($ per bushel)	t-Ratio
Winnipeg Barley	Long only	Oct. 1, 1974– Dec. 1, 1981	$2.87 $2.55	32	$0.03	.64
Winnipeg Barley	Long and Short	Oct. 1, 1974– Dec. 1, 1981	$2.87 $2.55	32	−$0.05	.86
Chicago Corn	Long only	Sept. 3, 1974– Dec. 1, 1981	$3.32 $2.66	36	−$0.07	1.07
Chicago Corn	Long and Short	Sept. 3, 1974– Dec. 1, 1981	$3.32 $2.66	36	−$0.04	.89

in a thin market the contract prices may be underestimates of their true value.

The theory of normal backwardation suggests that if a market is persistently favouring the "longs" over the "shorts" then a speculative strategy of maintaining a long position in the futures market should earn positive profits over time. The hypothetical Gray trading routine was tested in this section and it involves purchasing each futures contract on the first trading day in the delivery month of the preceding futures contract and then selling it on the first trading day of its own delivery month. For example, on October 1, 1974, the December (1974) futures contract was purchased; the December (1974) contract was subsequently sold on December 2, 1974, and the May (1975) contract was simultaneously purchased. Then, on May 1, 1975, the May contract was sold and the July contract was purchased, and so on. The routine strategy was initiated on October 1, 1974 and terminated on December 1, 1981 and the results are displayed in Table 3. The data set used for this test of normal backwardation was expanded to three years beyond that used for the martingale hypothesis primarily because this section is a test for long-run market behavior. Recall that the martingale hypothesis is related to very short-run price behavior.

In addition to the Gray routine, Cootner's interpretation of the theory was also tested. This involved a similar hypothetical buying and selling routine except that speculators were assumed to go long only after the peak of short hedging following the harvest period. The results reported in Table 3 for the long and short positions (the Cootner test) assumed speculators were short in the barley market from October 1 through December 1, otherwise they were long. In corn, they were assumed to be short from September 1 through December 1, and otherwise long.

For the long only routine, an average profit of $0.03 per bushel per trade for barley futures was earned before brokerage fees. This profit is not statistically different from zero because its t-ratio is 0.64 and the level at which the null hypothesis of a zero profit is rejected is a 0.05 t-value of 2.0. A similar routine strategy applied to the corn futures market in Chicago resulted in a negative average return of $0.07 per bushel. Statistically, this figure is not different from zero either. These results are to be expected in an active futures market where the Keynesian risk premium is bid close to zero.

The long and short trading routine did not result in improved average profits for barley and it only improved corn profits marginally. Barley profits fell from $0.03

(per bushel) per trade to −$0.05 per trade while corn rose from −$0.07 to −$0.04. These results allow for both long and short speculative positions and they are also a rejection of the theory of normal backwardation for barley and corn.

The information in Table 3 thus indicates the Winnipeg barley market is not persistently biased in favor of the speculators over the hedgers under the assumption that speculators are generally net buyers and hedgers are net sellers. Profits from maintaining a long position in the barley market between 1974 and 1981 are not statistically different from zero and based on this evidence the barley market cannot be considered a thin market relative to corn.

Quality of Price Information: Forecasting Ability

One further measure of how well the barley futures market is performing as a price-determining institution is to test its forecasting ability. Jerome Stein has shown there is a direct connection between futures price forecast errors and economic welfare. He suggests that the forecasting accuracy of the futures price is a more valid and worthwhile measure of market efficiency than is a statistical test of the stochastic nature of futures prices because a poor price forecast will result in misallocated resources.

The forecasting accuracy of the Winnipeg barley and Chicago corn futures markets is estimated in this section by the mean square prediction error[3] (MSE) for each series over a number of crop years. The lower the MSE, the more accurate the price forecast. The time period studied closely corresponds to that in the study of long-run market returns in Table 3. There is not an exact correspondence because this section is forecasting seasonal price performance.

Table 4 reports the time series chosen to represent price forecasts and the MSE results. The planting-time barley futures price forecast is taken as the price of December barley futures at planting time. For the 1975–76 crop year, the price of December barley futures on May 27, 1975 is the forecast of the post-harvest price for that year. The planting-time date varies because in 1975 and 1978 December barley futures were not traded until the month of May. For the other years, April 30 was chosen as the planting-time date and the April 30 prices of the December futures contracts were also chosen for corn.

The computed MSEs for the barley and corn forecasts are 608.40 and 513.15, respectively. These results indicate that the

TABLE 4. Planting Time and Post-Harvest Feed Barley and Corn Prices: 1975–81 ($ per metric ton).

Year	Planting-Time Barley Futures Price[a]	Post-Harvest Barley Futures Price[b]	Planting-Time Corn Futures Price[c]	Post-Harvest Corn Futures Price[d]
1975	96.91	110.23	100.78	100.39
1976	99.94	91.70	103.54	94.48
1977	92.60	75.00	101.96	86.61
1978	77.10	74.10	96.45	86.61
1979	89.10	118.00	107.47	106.69
1980	113.40	155.00	116.53	143.30
1981	154.50	120.90	147.63	98.03
Mean Square Error	608.40		513.15	

[a] Price of December barley futures on or about April 30th.
[b] Closing December barley futures price, end of December.
[c] Price of December corn futures on or about April 30th.
[d] Closing December corn futures price, end of December.
Source: Winnipeg Commodity Exchange, *Statistical Annual* (various issues). Chicago Board of Trade, *Statistical Annual* (various issues).

[3] If one has n pairs of predicted and actual prices, P_i and A_i, respectively, then the mean square prediction error (MSE) for the set of all n crop years is given by:

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (P_i - A_i)^2.$$

Chicago corn futures does a superior job of indicating post-harvest prices compared with the Winnipeg barley futures market. Using Stein's criterion for market efficiency, these figures thus show the barley futures market to be inefficient relative to the corn market.

Upon further examination of Table 4, it is clear that the barley market provided a particularly low price forecast in the spring of 1979.[4] It was low relative to corn primarily because the Canadian domestic market was burdened with barley stocks at the time and the CWB could not adequately arbitrage the domestic and international markets because of reported transportation problems (CWB). Recall that the barley futures price is for domestic transactions only and thus in 1979 it was reflecting domestic conditions which were those of surplus supply. The 1978–79 barley carryover to production ratio was 0.31, which is approximately double the normal level. The barley futures price was, therefore, not reflective of world supply and demand conditions at the time.

The inference from Table 4 is that institutional rigidities which periodically separate the Canadian barley market from the world market adversely affect the pricing efficiency of the barley futures market.

The relatively poor price information transformed in the spring of 1979 impacted on barley production levels as barley acreage fell by about 12 percent and then subsequently barley carryover was historically low at the end of the 1979–80 crop year. Had there been proper arbitrage between the domestic and world markets that year, the futures price would have provided a higher price forecast and farmers would have produced more barley. As a consequence, they would have had a greater opportunity to take advantage of attractive prices in the 1979–80 crop year.

Basis Behavior and Hedging Opportunities

The traditional purpose and benefit of producer hedging[5] on the futures market is to minimize possible revenue losses associated with adverse cash price changes. By taking equal but opposite positions in the cash and futures market, hedgers "play off" price fluctuations in the markets against one another and the effect of price variability on their income level is thereby neutralized.

One can define the hedging activity as exchanging price risk for basis risk; the basis being defined as the nearby futures price minus the cash price. The textbook example of a perfect hedge occurs when cash and futures prices are perfectly correlated and thus the basis does not change from the time the hedge is placed until it is lifted. Normally, the basis does have some variability, however, and hedging cannot completely eliminate price risk. It will reduce price risk, but only as long as the basis variability is less than the cash price variability.

In order to study the effectiveness of hedging, weekly price data were collected for feed barley and corn for the August 1977–December 1981 period. It was assumed that hedging would be carried out on a near-term futures contract no closer than six to eight weeks away. The data include mid-week closing prices for near-term WCE barley futures, Thunder Bay cash barley prices, Manitoba barley street

[4] Excluding the 1979 forecasts from the MSE analysis in Table 5 provides a MSE of 570.6 for barley and 598.57 for corn, which implies barley becomes the more efficient market. Had it not been for the inability of the market to reflect world conditions in the spring of 1979, the results on forecasting efficiency would be consistent with the other efficiency tests in this paper.

[5] Alternative motives for hedging arise from either anticipating favorable basis changes or attempts to diversify a portfolio by including futures contracts in the portfolio.

TABLE 5. Level and Variability of Feed Barley Mid-Week closing Prices: 1977–81 ($ per tonne).

Price Series	Mean	Standard Deviation
Near-Term Thunder Bay Barley Futures[a]	107.65	28.52
Thunder Bay Cash[b]	107.44	28.32
Montreal Cash[c]	128.64	32.57
Manitoba Street[d]	88.18	27.06
Alberta Street[e]	85.01	26.94
Near-Term Chicago Board of Trade Corn Futures[f]	112.97	21.09
North-Central Illinois Cash[g]	99.16	19.23
Montreal Basis	−20.61	4.92
Thunder Bay Basis	.21	3.86
Manitoba Basis	19.55	3.88
Alberta Basis	22.63	4.32
Illinois Basis	13.80	5.02

[a] Closing price of futures contract used by line elevator companies to arrive at the street price. The expiry date of the nearby contract is normally not closer than six to eight weeks away. Source: United Grain Growers daily price cards.
[b] No. 1 feed barley. Source: Winnipeg Commodity Exchange, *Statistical Annual* (various issues).
[c] C.I.F. Montreal price for No. 1 feed barley. Source: Livestock Feed Board of Canada.
[d] No. 1 feed barley. Source: U.G.G. daily price cards.
[e] No. 1 feed barley. Source: U.G.G. daily price cards.
[f] Closing price of nearby Chicago Board of Trade corn futures contract. The expiry date of the nearby contract is not closer than 90 days away. Source: Chicago Board of Trade, *Statistical Annual* (various issues).
[g] North-Central Illinois bid cash corn price (No. 2 yellow). Source: U.S.D.A., *Grain and Feed Market News.*

prices, Montreal cash barley prices, Alberta barley street prices, CBT corn futures and Illinois cash corn prices. The street prices in western Canada were those quoted by United Grain Growers, a farmer-owned grain company, which has operations throughout the prairies. These street prices are bids at rural primary elevators and are assumed to be representative of those offered to farmers by commercial grain companies. The Illinois corn prices are cash bids in north-central Illinois. Table 5 presents a summary of statistical information on these various price series for barley and corn. The table gives the mean and standard deviation for each price series.

If we define price risk as price variability then we can informally evaluate the usefulness of these futures markets for hedging by comparing the ratio of basis risk to price risk. The smaller this ratio the more useful the market is as a hedging mechanism. From Table 5 we find that the basis risk is much smaller than the price risk for each of the series. This is measured by the ratio of the standard deviation of the basis to that of the price. The ratios are small and in the range from 0.14 to 0.16 and thus for any one of the delivery points represented in Table 5 the barley and corn futures market can be used to reduce exposure to price variability.

To more formally test the effectiveness of hedging, following Ederington, one can show that a measure of the minimum-risk hedge ratio X_f^* and hedging effectiveness (E_f^*) is a function of the covariance between cash (or street) and futures price changes and the variance of futures price changes. Once the crop is planted or in store, the objective function for the risk-averse hedger, aiming to reduce price variability, is:

$$\min \mathrm{Var}(P_{Ht}) = \mathrm{Var}(P_{st}) + X_f^2 \mathrm{Var}(P_{ft}) X_f^* + 2X_f \mathrm{Cov}(P_{st}, P_{ft}) \quad (3)$$

s.t.:

$$P_{Ht}^{\circ} = E(P_{st}) + X_f E(P_{ft}) \quad (4)$$

where P_{st} and P_{ft} are, respectively, the cash (or street) and futures price changes during period t. The target change in value of the portfolio of cash and futures positions during period t is equal to P_{Ht}° and the proportion of the commodity which is hedged equals X_f, with X_f^* being the optimal hedge ratio. It is assumed the proportion of the cash commodity held in storage is fixed at 1.0 and, therefore, it does not appear explicitly in the expression. The maximum reduction in price variance is achieved by hedging an amount equal to X_f^*.

The first order condition for the hedger is:

$$\frac{\partial\, Var(P_{Ht})}{\partial X_f} = 2X_f Var(P_f) + 2\, Cov(P_s, P_f) = 0. \quad (5)$$

Solving (5) for the optimal ratio we have:

$$X_f^* = \frac{-Cov(P_s, P_f)}{Var(P_f)}. \quad (6)$$

From (6) we find the optimal hedge ratio equals the negative of the slope coefficient of a regression of P_{st} on P_{ft}. In addition, the coefficient of determination from this regression gives us an estimate of E_f^*, the measure of hedging effectiveness. The coefficient of determination measures the proportion of the variance in cash price changes that futures price changes explain. Assuming the optimal hedge is carried, E_f^* can thus be interpreted as the average proportional reduction in price change variance that could have been realized by hedging.

The results of an analysis of the hedging effectiveness of barley and corn futures for the 1977–81 period are given in Table 6. An ordinary least squares regression of the form in (7) was run on mid-week cash and futures price changes.

$$P_{st} = \alpha + \beta\, P_{ft} + \epsilon_t \quad (7)$$

For hedge ratios set equal to the estimated β coefficients, the R^2 values give the proportionate reduction of price risk attainable. For example, a hedger selling on the Alberta street market, who maintained 86 percent of his barley inventory hedged, would have reduced his price risk by 58 percent between 1977 and 1981. The reason the minimum risk hedge ratio is smaller than 100 percent is that, on average, the street price changes proportionately less than the futures price from week to week. The direction of change of street and futures prices is similar, however.

TABLE 6. Estimates of Effectiveness of Hedging Barley and Corn: 1977–81.

	Regression Coefficients			
Cash Market	α (t-Value)	β (t-Value)	R^2	d.w.
Thunder Bay Barley	.03 (.18)	.74 (13.52)	.47	2.16
Montreal Barley	.12 (.72)	.61 (11.22)	.40	1.98
Manitoba Barley	.00 (−.02)	.83 (17.62)	.60	2.25
Alberta Barley	.03 (.23)	.86 (17.05)	.58	2.31
Illinois Corn	.00 (.23)	.60 (11.15)	.35	2.18

Hedging stocks in the Thunder Bay cash barley market is shown in Table 6 to be less effective than hedging at rural delivery points in other parts of western Canada. It is estimated that with the optimal hedge, a hedger would have reduced his price risk by 47 percent in Thunder Bay compared with between 58 to 60 percent in the rural country markets of Alberta and Manitoba. The E_f^* estimate for Montreal barley is 40 percent compared to the rural Illinois corn estimate of 35 percent.

The basis on the Canadian prairies is very stable compared with the other markets in Table 6 for two major reasons. The first is that the majority of rural open-market commercial barley sales are destined for only the one terminal position in Thunder Bay. In the U.S., on the other hand, the corn basis is more variable because there are many different competing terminal destinations for the commodity. A second factor explaining the relative stability of the Canadian rural basis is that the freight and elevation costs are regulated by the federal government and are essentially fixed from year to year. On the

TABLE 7. Estimates of Hedging Effectiveness Allowing for Changing β Coefficients: 1977–81.

Cash Market	Regression Coefficients (t-Values in Parentheses)							
	α	β_1	β_2	β_3	β_4	β_5	R^2	d.w.
Thunder Bay Barley	.04 (.25)	1.01 (3.33)	.16 (.42)	−.42 (−1.29)	−.24 (−.76)	−.35 (−1.08)	.49	2.11
Montreal Barley	.13 (.72)	.99 (3.69)	−.26 (−.73)	−.51 (−1.70)	−.34 (−1.20)	−.47 (−1.59)	.41	1.95
Manitoba Barley	.01 (.08)	1.16 (4.50)	−.26 (−.81)	−.59 (−2.13)	−.21 (−.79)	−.40 (−1.46)	.62	2.14
Alberta Barley	.06 (.43)	.52 (.187)	.49 (1.42)	.10 (.34)	.44 (1.51)	.36 (1.21)	.60	2.24
Illinois Corn	.00 (−.33)	.67 (2.96)	.18 (.63)	.07 (.30)	.08 (.31)	−.32 (−1.32)	.39	2.18

other hand, these major components of the basis are determined by supply and demand factors in the U.S. and thus the Illinois basis is more variable.

It is also worthwhile to explore the extent to which the estimated minimum variance hedge ratio β in Table 6 is stable from year to year. Since we are dealing with time series data, the stability of the estimated parameters can be investigated with the use of dummy explanatory variables.

We can accomplish this by rewriting equation (7) as:

$$P_{st} = \alpha + \beta_1 P_{ft} + \beta_2 \cdot D_1 \cdot P_{ft} + \beta_3 \cdot D_2 \cdot P_{ft} + \beta_4 \cdot D_3 \cdot P_{ft} + \beta_5 \cdot D_4 \cdot P_{ft} + \epsilon_t \quad (8)$$

where:

D_1 = 1 for observations in 1978
= 0 otherwise
D_2 = 1 for observations in 1979
= 0 otherwise
D_3 = 1 for observations in 1980
= 0 otherwise
D_4 = 1 for observations in 1981
= 0 otherwise.

The β_2, β_3, β_4 and β_5 coefficients in equation (8) measure differences in slopes from year to year and the ordinary least squares result for equation (8) are shown in Table 7.

With the inclusion of the dummy variables the R^2 is slightly higher for all of the price series. The β coefficients associated with the dummy variables are for the most part statistically insignificant. Using the 5 percent level of significance the only exception is β_3 for Manitoba barley.

Using Manitoba barley as an example, the interpretation of these results indicate that in 1978 the optimal hedge would have been $\beta_1 + \beta_2 = 0.90$ (which is 90 percent of the inventory level) and the consequent reduction in price variance 62 percent.

In general, these estimates support those found in Table 6. There is some slight evidence of instability in the β coefficients but the level of hedging effectiveness is found to be high. Hedging barley in western Canada results in a greater proportionate reduction in cash price variance than does hedging corn in Illinois.

Conclusions

The pricing efficiency and hedging effectiveness of the feed barley grain futures market in Canada has been the subject of this study. The Chicago corn market was used as a norm and both the intertemporal and spatial behavior of futures and cash prices were analyzed. A market is deemed price efficient if it rapidly and accurately adjusts to a particular information set. Hedging effectiveness was measured by the stability of the basis.

Several weak-form tests, such as serial correlation analyses, price variability analyses and price-trend analyses, were performed on the barley and corn market prices. For the most part, the results of these statistical tests did not allow us to reject the hypothesis that the barley futures market is efficient. However, because efficiency is always defined relative to some particular information set, these results indicate the market does a good job of reflecting Canadian domestic information on supply and demand.

To test the market's adjustment to information on world supply and demand conditions, the planting-time forecasting ability of barley futures was compared with corn. It was clearly shown that in 1979 the WCE was inefficient in terms of being able to accurately forecast prices. During this period there was inadequate arbitrage between the Canadian domestic and world feed grain markets and the WCE did a relatively poor job of forecasting prices. The results of this paper provide empirical support to the notion that the performance of a futures market is largely determined by the institutional environment it operates within.

Finally, the barley market was found to have a relatively stable basis and the rural markets displayed a less variable basis than the terminal Thunder Bay market. Overall, hedging rural cash barley on the barley futures market reduces price risk more effectively than does hedging rural corn on the corn futures market.

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