LONG-TERM MEAN REVERSION RETURNS IN COMMODITY FUTURES MARKETS

By Dennis Jackson

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ABSTRACT

Desire for alternative long-term investment vehicles has increased considerably, and are well known to the public by such terms as "value investments" and "contrarian investments." These trading strategies buy under-priced assets and sell over-priced assets, with the expectation that price will moderate towards its true value in the long-term as suggested by mean reversion theory. If long-term mean reversion exists in commodity futures markets, then it may be useful for developing long-term trading and hedging strategies.

This study tests for long-term mean reversion in commodity futures markets using two long-term mean reversion commodity futures trading systems. The first system uses a fundamental model to calculate equilibrium futures prices, while the second system uses a technical model to calculate equilibrium futures prices. Long positions are entered when futures prices fall below equilibrium, and short positions are entered when futures prices rise above equilibrium. Positions are exited when futures prices moderate and revert back towards equilibrium. Trading performance is tested for corn, wheat, oats, and canola over the 1980-1997 period.

The two trading systems both appear to support the hypothesis that long-term mean reversion exists in commodity futures markets. Trading results show that both trading systems earn positive long-term returns, and also show that trading performance improves as reversion parameters are increased. The fundamental system earns average monthly returns of 3.0 percent and the technical system earns average monthly returns of 2.6 percent.

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CHAPTER 1

INTRODUCTION

Mean reversion theory states that asset prices tend toward an equilibrium value. Seminal articles by De Bondt and Thaler (1985, 1987) examine returns to stock market investments and show that stocks outperforming the market in earlier periods subsequently underperform the market in later periods. Various mean reversion studies expand their research of the stock market, and some studies also research mean reversion in futures markets.

Mean reversion implies that prices diverge from equilibrium value, which goes against efficient markets theory. Efficient markets are thought to be constantly in equilibrium, and price movements can not be predicted ahead of time. However, some evidence does suggest that mean reversion may exist in futures markets. Bessimbinder, Coughenour, Seguin, and Smoller (1995) examine the term structure of futures markets and find evidence of mean reversion in agricultural commodities. Cutler, Poterba, and Summers (1991) show that asset prices may be positively correlated over short horizons but that prices may be negatively correlated over longer horizons. Irwin, Zulauf, and Jackson (1996) regress returns on past returns, with asymptotic results suggesting that mean reversion exists in agricultural futures markets and with results from Monte Carlo analysis suggesting the contrary, suggesting that small samples explain why previous studies support the hypothesis of mean reversion in futures markets.

However, most studies cannot avoid the problem of small samples associated with long horizon mean reversion research, so more studies are needed to help explain long-term mean reversion in futures markets. Market participants may be able to use this information to improve their ability to price assets, and may allow them to reduce costs associated with acquiring information and may improve market efficiency. It may also expand the empirical knowledge concerning mean reversion and the value of public information in commodity futures markets.

This study examines whether grain futures markets revert toward equilibrium value over the long-term, with the mean reversion horizon considered in this study being longer than most horizons considered in previous studies. Mean reversion may be related to factors such as uncertainty of supply and demand, market cycles, overreaction, or the cost of production, and the effects of such factors may be more evident over longer horizons. If positive returns can be earned by incorporating mean reversion theory into a long-term futures trading system, then mean reversion may exist in grain futures markets over longer-term horizons.

The objectives of this study are therefore to test for long-term mean reversion in commodity futures trading using a mean reversion model. Equilibrium futures value is calculated, then mean reversion theory is used to select long-term positions in the futures market. Long positions are entered when current futures prices fall below equilibrium and short positions are entered when current futures prices rise above equilibrium, with levels and variability of trading returns analyzed to illustrate potential profits and potential risks.

Fundamental analysis involves economic analysis of market conditions to determine prices and market direction. Chapter two uses fundamental analysis to test whether long-term mean reversion exists in grain futures markets, with equilibrium grain futures prices calculated using United States Department of Agriculture estimates of ending stocks and usage. The grain futures contracts to be studied are oats, wheat, corn, and canola, and are traded over the 1980 to 1997 period.

Technical analysis tries to identify patterns in past prices only, and does not consider fundamental market conditions. Chapter three uses technical analysis to test for long-term mean reversion in grain futures markets, and defines equilibrium value as the long-term average of historical futures prices. Chapter three then proceeds as in chapter two, using the same commodities and the same trading period.

Chapter four is a summary of chapters two and three. It compares the trading results of the fundamental model with the trading results of the technical model and highlights important differences, and direction for future research is also suggested.

CHAPTER 2

LONG-TERM MEAN REVERSION RETURNS AND FUNDAMENTAL ANALYSIS IN COMMODITY FUTURES MARKETS

Introduction

Fundamental analysis attempts to examine economic factors affecting asset supply and demand in order to determine fundamental value. Prices may diverge from fundamental value because of factors such as uncertain supply and demand conditions, overreactions, and cycles, but in the long-term adjustments to supply and demand are expected to occur which guide prices toward fundamental value.

The hypothesis that asset prices revert to fundamental values is sometimes referred to as mean reversion. Mean reversion suggests that prices of undervalued assets increase and prices of overvalued assets decrease toward their fundamental asset values. Also, mean reversion implies the further that prices diverge from fundamental values the greater the expected reversion of prices toward fundamental values.

This study attempts to provide new evidence and expand the body of knowledge regarding long-term mean reversion in futures markets. This study allows for the possibility that mean reversion occurs over considerably longer time periods than those considered in most earlier research. In this study, the possibility is considered that grain futures prices can revert toward fundamental futures value over a number of years. Earlier research may not have seriously considered such a long period because futures contracts are sometimes considered to be only short-term instruments. As well, there is a limited amount of data available for long-term studies, which may have deterred some researchers from studying long-term mean reversion in futures markets. Further, the methodology of this study differs from most earlier studies since it incorporates fundamental information into a fundamental mean reversion model, while some other studies that use returns to demonstrate mean reversion generally consider only past prices, or a technical model.

This study attempts to test for mean reversion in commodity futures markets by analyzing returns from a commodity futures trading system that uses long-term mean reversion based on fundamental analysis. Futures prices may differ from fundamental equilibrium futures values because of uncertainty or overreactions, but economic forces may adjust in the long-term and cause futures prices to revert toward their fundamental values. If futures prices return to long-term fundamental values then positive long-term trading returns may be possible, and these returns may be considered as evidence that support long-term mean reversion. Since grain futures markets appear to have a number of economic conditions which may support mean reversion, grain futures mean reversion is examined in this study.

The objectives of this study are to 1) test for long-term mean reversion in commodity futures markets for grains based on the level of returns from a long-term fundamental mean reversion model, and 2) analyze the variability of these returns.

Theory

Mean reversion theory states that asset prices tend towards an underlying fundamental value. If prices diverge sufficiently from their fundamental value then economic forces are expected to intervene and return prices to their fundamental value in the long-term.

Reasons for Mean Reversion

According to economic theory, prices should be affected as supply and demand changes are realized, with prices increasing during relative "shortages", and decreasing during relative "surpluses." These economic forces should pressure markets to revert to economic equilibrium, with economic equilibrium price levels approximating fundamental value.

Fundamental value should be related to the cost of production according to economic theory. When prices rise above the cost of production, producers increase profits by increasing output. The increase in output is expected to cause prices to fall back towards the cost of production. If prices fall below the cost of production then producers are expected to reduce output levels to cut losses, and the reduced output is expected to increase prices.

Pricing of agricultural futures is complicated by the fact that there is a time lag of several months, or perhaps longer, between the time that production decisions are made and the time that the product is ready to market. Production decisions then depend on expected prices at harvest which are not known with certainty. Producers must produce the market clearing level of each commodity, as indicated by expected price, without knowing the actual market clearing level. As a result, the amount of the commodity produced may not be at the market clearing level. If supply differs considerably from the market clearing level then there may be considerable movements in price to clear the commodity market, with potentially large uncertain movements and overreactions offering possible opportunities for mispricing to occur.

Further to complicate production decisions, the amount of the commodity that will be produced is not known with certainty. Production is stochastic around an expected level as determined by climate and may result in a quantity being supplied that is different from expectations. Prices may then become higher or lower than previously expected in order to clear the commodity market. This uncertainty may result in large price movements if production is substantially different from expectations, and it is possible that there may be at least slight errors in pricing if overreactions occur along with such large price movements.

The relatively inelastic supply and demand conditions in agricultural markets may also imply large price changes and high price volatility relative to changes in quantity, as suggested by basic cyclical models. Production is somewhat fixed within the production season, which contributes to the inelasticity of supply. Also, production is somewhat inelastic from one season to another because changes to production may be limited by crop rotation patterns, climate limitations, asset fixidity, or managerial abilities of producers. Since production is relatively inelastic, large price movements and overreactions may occur for relatively small changes in production, and may provide more opportunities for mean reversion of prices than more elastic commodities.

Inelastic demand for agricultural commodities is also expected to be associated with large price changes relative to changes in quantity. Tastes, preferences, population, and income do not quickly change, and may help to cause demand for food to be relatively inelastic and relatively unresponsive to changes in price. Changes in quantity demanded may not be able to completely moderate extreme price movements resulting from supply shocks, overreactions, and information uncertainty, and may result in mispricing or divergence of futures prices from mean levels.

Evidence of Mean Reversion

Jackson, Zulauf, and Irwin (1991) present evidence that agricultural futures prices are mean reverting. Their results from market timing tests tend to support the hypothesis that futures prices are mean reverting. They also show that some positive trading returns could have been theoretically earned by traders using a mean reverting trading system over the 1975-1989 period, providing further evidence to support the hypothesis that futures prices may be mean reverting. Their results also show that fundamental value of agricultural commodities may be related to cost of production. Their results indicate that mean reversion may exist in futures markets and that it may be possible to develop a profitable trading system from mean reversion theory. Their results also suggest that fundamental economic factors may be important to determining futures prices.

However, Irwin, Zulauf, and Jackson (1996) examine mean reversion of commodity futures prices using Monte Carlo analysis. Their results show that asymptotic regression tests appear to support the hypothesis of mean reversion while Monte Carlo analysis tends not to support the hypothesis of mean reversion, and suggest that small sample bias may explain much of the asymptotic regression results supporting long-term mean reversion in commodity prices. However, most studies cannot avoid the problem of small samples associated with long horizon mean reversion research, so more studies are needed to add to the overall sample of existing research and help explain its implications.

Evidence of Returns From Fundamental Information

The most widely regarded source of supply and demand information for agricultural commodities is the United States Department of Agriculture (USDA). These reports are generally considered to be the most popular representation of supply and demand that are available due to the extraordinary amount of resources that are employed in obtaining the information.

There is extensive literature examining the impact of USDA reports on commodity prices. Research generally concludes that USDA reports do provide useful information to market participants, particularly in the days surrounding the release of reports. Fortenbery and Sumner (1993), Mann and Dowen (1996, 1997), Colling and Irwin (1990), McNew and Espinosa (1994), Baur and Orazem (1994), and Milonas (1987) provide some evidence that information released in USDA reports is important to futures pricing. These studies generally show that fundamental information is important, and therefore may be useful in estimating long-term fundamental values.

Epps and Kukanza (1985) develop a trading model for corn, wheat, and oats futures using fundamental economic variables as independent variables in a regression model. These independent variables include crop forecasts, grain stocks, and futures prices for complement and substitute commodities, among others. They use the model to forecast market movements then use the forecasts to select positions in the market. Their trading systems hold positions in the market for only the last month prior to delivery on the contract. Their results show it may be possible to earn positive returns can be earned using this trading system.

Milonas (1994) develops a short-term trading rule that attempts to earn excess returns from price changes related to information contained in the USDA report. A position is taken in the market prior to the release of the report then exits the market a few days after the contents of the report become known. The study shows that it may be possible to earn earn positive returns using this system by trading soybeans but it may not be possible to earn positive returns by trading corn.

Carter and Galopin (1993) study USDA *Hogs and Pigs* reports to see if advance knowledge of information contained in the report could be used to generate trading profits. They hypothesize that being willing to pay for prior knowledge of information contained in USDA reports is sufficient to show that the reports have economic value. Their results indicate that hog futures prices react to the release of the *Hogs and Pigs* report but do not show that profits can be earned from prior knowledge of the report. They conclude that traders would be unwilling to pay for advance knowledge of the report because information contained in the USDA *Hogs and Pigs* report is already incorporated into prices. However, Colling and Irwin (1995) question their research, stating that the risk premium used is too high, and that it may explain what they consider to be contradictory results.

In a semi-strong form efficient market it should be impossible to earn positive trading returns using publicly available information. Similarly, advance knowledge of publicly available information should permit trading systems to earn positive returns. Thus, the results of the above trading system studies may be unexpected and imply market inefficiencies, but this may also imply that futures prices diverge from fundamental value. If futures prices do sometimes diverge from fundamental value, then a trading system incorporating the mean reversion hypothesis that futures prices revert to fundamental value may earn positive returns.

Impact of Fundamental Information

Garcia, Irwin, Leuthold, and Yang (1997) find somewhat contradictory results regarding the value of public information in commodity markets. They find that USDA reports are comparable in accuracy to privately prepared reports released in advance of the USDA reports. They still find that traders react to USDA reports and are willing to pay for advance knowledge of them. Garcia et al. suggest these apparently contradictory results can be reconciled if USDA forecasts are considered to be less risky than private forecasts. However, despite this explanation, their results may still imply that a trading system could be developed that earns positive returns using fundamental information.

Colling, Irwin, and Zulauf (1996) propose that the importance of USDA reports may depend upon the market cycle. They study the price reaction of corn, wheat, and soybeans from 1988 to 1991 to unanticipated information dependent upon the state of the market, where the state of the market is separated into high, middle, and low stocks to use ratios. They suggest that reports may have greater impact when supply and demand is not in an equilibrium relationship. They show that price reaction is generally limited but that soybean price movements may be conditional upon the state of the market and that corn price movements may be conditional upon the time of the year. Their results provide reason to believe that market conditions may be important to determining futures price movements. Reports may be more valuable during certain market conditions implying that conditional market conditions should be considered when developing a trading system.

In a related study, Mann and Dowen (1998) study market cycle and seasonality impact on reaction of live hog and pork belly futures prices to Cold Storage Reports. They show that market cycle does not have a statistically significant impact on reactions to reports, but seasonality does have a significant impact on reaction to reports, further suggesting that reaction to USDA reports may be conditionally determined.

Mean reversion theory suggests that prices revert toward fundamental values in the long-term, and in light of these articles it appears that fundamental information is important to determining fundamental values of futures prices. However, it is not clear that fundamental information is always appropriately incorporated into futures prices, so sometimes futures prices may diverge from fundamental values. If it is possible to earn positive returns by incorporating long-term mean reversion theory into a fundamental model, then positive returns can be considered as evidence of long-term mean reversion.

Data and Procedure

Data used in this study to test for mean reversion consists of agricultural commodity futures, specifically grains. Grains have extensive series of data for both futures contracts and other fundamental data. This data may not be as easily obtainable for other commodities and the price series may not be as long. Since agricultural commodities generally have relatively inelastic supply and inelastic demand schedules then it is expected that they may be more susceptible to shocks such as weather than other commodities, and subsequently may provide high price variation and more interesting mean reversion results than other less volatile commodities.

The United States Department of Agriculture World Agricultural Outlook Board produces monthly reports of supply and demand for domestic and world markets called World Agriculture Supply and Demand Estimates (WASDE). These reports provide estimates of usage and ending stocks for major grains, and are used in this study to estimate equilibrium futures prices.[1] These reports are assumed to be the best estimates of the actual market situation and are held in similarly high regard by a number of market participants, among other statistics.

Continuous futures prices examined in this study are May oats, September corn, May wheat, and September canola.[2] These specific delivery months are selected to coincide with USDA World Agricultural Supply and Demand Estimates (WASDE) of year end stocks. Open positions are rolled over from contracts in one year into contracts with the same delivery month in the following year. Rolling over open positions occurs on the 15th day, or the next available trading day, of the month preceding the delivery month. For example, a position in the 1996 May oats contract is rolled over by exiting the position on approximately April 15, 1996, then entering a position in the 1997 May oats contract on April 16, 1996. Rolling over open positions at this time helps to avoid problems associated with liquidity, squeezes, or forced acceptance of delivery that may occur as the delivery date approaches. The wheat and corn price series begin in 1968, oats begins in 1967, and the price series used for canola begins in 1973, and all price series end in 1997. Daily opening and closing futures prices are used in this study and are provided by Technical Tools.[3] Oats, corn, and wheat trade on the Chicago Board of Trade while canola trades on the Winnipeg Commodity Exchange.

A five-step procedure is used in order to generate equilibrium closing futures prices and returns from a long-term fundamental mean reversion model:

(1) Daily closing futures prices and monthly WASDE stocks to use data are aggregated into annual data series.

(2) Annual regression models are estimated with closing futures price as the dependent variable and stocks to use as the independent variable, with data prior to 1980 and they are updated and re-estimated annually for each year (1980, 1981,..., 1997). This results in 18 sets (years) of annual regression coefficients for each commodity over the entire period.

(3) Monthly equilibrium closing futures prices are projected from the annual regression coefficients above in (2), by inputting monthly WASDE data into the annual regression coefficients.

(4) The daily closing futures price is compared each day with the projected monthly equilibrium closing futures price in (3) to determine whether the daily closing futures price has diverged from the projected monthly equilibrium closing futures price.

(5) Positions are taken in the futures market on the next day's opening price as given by a trading rule, with long (buy) positions generated when closing futures prices are below projected monthly equilibrium closing futures prices and short positions generated when closing futures prices are above projected monthly equilibrium closing futures prices. Positions are taken conditional on the amount of difference between closing futures prices and projected monthly equilibrium closing futures prices.

Evidence of positive monthly returns would then support the hypothesis that long-term mean reversion exists in futures markets. Details of the equilibrium model, trading rule, trading rule parameters, and trading model are presented below.

Equilibrium Model

The model used to estimate long-term equilibrium futures prices (fundamental value) should adjust for fundamental economic supply and demand factors. To facilitate practical use by traders and to facilitate replication, the model should be of a simple form and have few variables. These characteristics should allow the model to be robust and to be applicable to several different commodities.

A single equation model is estimated for long-term equilibrium futures price using a regression model. This model uses the ratio of total ending stocks to total use as the independent variable. The stocks to use variable is commonly considered to be the most important variable in gauging supply and demand conditions and should adequately model their effects on price, and captures the information contained in many other supply and demand variables. As the ratio of total ending stocks to total use decreases, indicating a shortage of the commodity, price is expected to increase. As the ratio increases, indicating that disposition is easing, price is expected to decrease.

The equilibrium futures price model to be estimated is:

(1) $F_t = a + b * (ES_t / USE_t)$

where F_t indicates the futures price with a delivery month that coincides with the end of crop year t, ES_t is the total ending stocks at the end of crop year t as estimated by the USDA, USE_t is the total domestic use at the end of crop year t as estimated by the USDA, and a and b are the coefficients to be estimated.

The model is re-estimated annually using average annual futures prices and annual WASDE estimates of total use and total ending stocks. Annual data, constructed by aggregating the original futures prices and the WASDE data, is used to reduce the possibility of noisy market movement. The model is initially estimated with data up until 1980 and is then re-estimated annually by adding the new data available from the most current period. Re-estimation allows the model to use new information as changes occur in the data.

The model is re-estimated annually, but each month the annual coefficients are used to compute equilibrium futures prices. Equilibrium futures prices are compared with closing futures prices on a daily basis to determine trading activity, according to the trading rule.

Trading Rule

Define equilibrium as the long-term futures price estimated above, and

Enter:

(1) *Go long (buy)* when current daily closing futures prices *fall below* equilibrium futures price, e.g. *fall* one mean squared error below equilibrium.

(2) *Go short (sell)* when current daily closing futures prices *rise above* equilibrium futures price, e.g. *rise* one mean squared error above equilibrium.

Exit:

(3) *Exit* above positions when current futures prices *return towards* equilibrium, e.g. *return* to 0.6 mean squared errors from equilibrium.

(4) Market positions may be long, short, or neutral (out of the market).

Mean squared error is a measure of price variation from the estimated regression line. If prices are normally distributed from the regression line then approximately 68 percent of all observations are contained within one mean squared error from the regression line, approximately 87 percent of all observations are contained within one and one-half mean squared errors from the regression line, and approximately 95 percent of all observations are contained within two mean squared errors from the regression line. This idea relating probability to mean squared error provides intuitive statistical and economic reasoning for testing entry and exit at several levels of variation from equilibrium to observe the effects upon returns.

Trading Rule Mean Reversion Parameters

Long-term mean reversion toward fundamental value is tested by examining trading results for three values of the mean reversion parameter. A *small* amount of reversion is tested by entering the market when current futures prices reach one mean squared error away from equilibrium then exiting the market when current futures prices revert to 0.6 mean squared errors away from equilibrium. An *intermediate* amount of reversion is tested by entering the market when current futures prices reach 1.5 mean squared errors away from equilibrium then exiting the market when current futures prices revert to 0.3 mean squared errors away from equilibrium. A *large* amount of reversion is tested by entering the market when current futures prices reach 2.0 mean squared errors away from equilibrium then exiting the market when current futures prices revert all the way back to equilibrium. Closing prices are used to generate trades, with trades occurring on opening prices.

Trading Model

The system is designed in such a manner that traders could implement it. Mechanical trading procedures and computation of returns used in this study are similar to procedures of large commercial users or commodity funds. Trading commences one year prior to delivery on the 1980 futures contract and ends on December 31, 1997, allowing for approximately 18 ½ years of out of sample trading results. The decision to use the 1980 contract as the starting point is somewhat arbitrary. It is selected because all commodities being studied have a considerable amount of data available prior to the 1980 contract. The data available prior to the 1980 contract is used to initially estimate the model, with this relatively long initialization period ensuring that data is sufficiently representative of the long-term series.

Transaction costs, including brokerage fees and pricing slippage, are assumed to be $25 per trade or $50 for a round-turn. Twenty-five percent of equity is invested in initial margins and the remaining 75% of equity is set aside for margin calls, with initial margin requirements consistent with historical levels. Equity set aside is available to cover margin calls so that the system is not forced out of a position due to margin calls. Monthly percentage returns are then computed for the 18 year period from Jan. 1, 1980 to Dec. 31 1997 for each commodity.

Results

Mean Return Levels

Table 2.1 shows monthly return statistics for the three levels of long-term reversion tested in this study. For the large reversion parameter, entries are generated when current futures prices reach 2.0 mean squared errors from equilibrium and exits are generated when current futures prices revert all the way back to equilibrium. Monthly returns averaged 3.0 percent across commodities for this large mean reversion parameter. All four commodities studied are significant at the ten percent level in two-tailed t-tests, but no commodity is significant at the five percent level. Monthly returns are generally consistent across the commodities studied.

For the intermediate reversion parameter, entries are generated when current futures prices reach 1.5 mean squared errors from equilibrium and exits are generated when current futures prices revert back to 0.3 mean squared errors from equilibrium. These intermediate mean reversion parameter monthly returns average 1.9 percent across commodities. The returns observed are not statistically significant at the ten percent level for any commodity studied but they are lower than returns observed for the large reversion parameter.

For the small reversion parameter, positions are entered when current futures prices are one mean squared error away from equilibrium then are exited when futures prices revert back to 0.6 mean squared errors away from equilibrium. These small mean reversion parameter monthly returns average 1.1 percent across commodities. This is the lowest average return observed for the parameters examined in this study. Again, returns are not significant at the ten percent level for any commodity studied.

Results above support the hypothesis that futures prices revert toward long-term fundamental values, because returns are positive. Results suggest that this long-term fundamental trading system earns positive returns, and returns are statistically significant for the large reversion parameter which suggests that returns compensate for risk. As well, returns increase as reversion parameters are increased which is consistent with reversion theory. The consistency of results across commodities and across reversion levels provides reinforcing evidence to support the hypothesis that futures prices revert towards fundamental value.

This system appears to earn positive returns during periods of crop production shortfalls, when buyers want to ensure sufficient supplies to meet prior sales commitments and they are willing to pay high prices to guarantee supplies. Prices then moderate to normal levels when production levels are adjusted in response to extreme prices. It appears that this system earns positive returns either because traders overreact to market pressures, or because traders fail to fully incorporate expected changes in production decisions into distant contract prices in response to current price signals.

While it was expected that profitability of this system may be diminished when rolling positions from old crop contracts into positions in new crop contracts, this did not appear to happen to the extent expected. Since output for the new crop year is determined primarily by production decisions implemented at planting time, it was expected that new crop contracts would account for new crop production decisions that may occur to eliminate old crop shortages or surpluses, as indicated by extreme prices in old crop contracts.[4] As a result, it was expected that prices would jump discretely from extreme points in old crop contracts to equilibrium in new crop contracts, rather than move smoothly, and would remove a considerable amount of the opportunities available for profitable trading using mean reversion. However, it appears that profitable trading opportunities were not completely eliminated by rolling positions from old crop contracts into new crop contracts, as suggested by the positive returns earned.

Grains may be susceptible to larger price swings because they have relatively inelastic supply, combined with production being impacted by shocks in weather. As well, there is a time lag required for production that may magnify possible shortages, so discrepancies may result in large price movements. Large price movements due to relatively inelastic supply and demand schedules and uncertainty, especially uncertainty of weather, may make it difficult for traders to determine appropriate futures prices for the given market conditions and may cause prices to overreact to fundamental information.

Returns levels presented here are generally higher than returns to the mean reversion futures trading system presented by Jackson, Zulauf, and Irwin (1991). They present annual returns as high as 6.72 percent for corn and 12.04 percent for soybeans, and also present returns for some other agricultural commodities. Annualizing the monthly returns in this study shows that returns for the small reversion parameter are similar to the annual returns observed by Jackson, Zulauf, and Irwin (1991), but returns to the large reversion parameter are much higher. The differences in returns may be due to the length of the horizon considered, since Jackson, Zulauf, and Irwin (1991) consider horizons only as long as six months. Or, differences in returns may be because the trading system examined in this study incorporates fundamental information.

Mean monthly returns for wheat do not increase as much as returns for the other three commodities studied when mean reversion parameters used to generate trades are increased. Reverting price patterns may be less apparent for wheat than for some other commodities because wheat is often regulated by government policies which include government purchases of excess supplies, holdings of government owned wheat stocks, and distribution of wheat as foreign aid. Government policies may moderate market conditions and price movements that may otherwise be expected in an unregulated market, and may reduce returns from this trading system.

It may be more difficult to use this system to trade non-agricultural commodities because fundamental information may be less readily available and more costly to obtain. Fundamental models for agricultural commodities can be developed and maintained at a relatively low cost to individuals because governments collect and publish fundamental agricultural information. The cost to individuals to acquire fundamental information for other commodities may be significant and may discourage their development. However, it might be possible to use the idea that prices revert towards their fundamental value in order to develop an analogous long-term trading system for other commodities.

Mean monthly return levels presented here may be relatively conservative and may slightly understate actual returns for two reasons. First, returns from investing the 75 percent of capital in T-bills are not included in returns. Second, this system is in the market for only a limited amount of time. The rest of the time, while the system is out of the market, equity could be invested in other vehicles such as t-bills, bonds, or stocks.

These returns may exist because traders typically are unwilling to take long-term risks. This system provides positive returns to traders who are willing to take long-term risks and use low levels of leverage, while traders typically have a short-term outlook. Traders typically are relatively highly leveraged and are encouraged to produce returns with low variance for employers and investors. They are not willing to take relatively large drawdowns in equity because performance measurements are often concerned more with short-term performance than long-term performance.

Standard Deviation

Monthly returns are highly variable and increase as reversion parameters are decreased, which further suggests that futures prices revert toward fundamental value. Table 2.1 shows a standard deviation of 24.1 averaged across commodities for the large reversion parameter. Variability increases for the intermediate reversion parameter, as the average standard deviation rises to 24.3, and increases further for the small reversion parameter, to 26.1.

Standard deviation of monthly returns for oats is considerably larger than standard deviations observed for the other commodities studied, with this result being less obvious when the amount of reversion used to generate trades is increased. The dissimilar standard deviation of returns for oats appears to be a result of large losses to oats trading that occur during 1988, when prices to rise to very high levels after entering a short position. Futures prices do eventually fall and allow this particular trade to earn positive returns but the positive returns earned by this trade are highly variable, and demonstrate the risk associated with this system for trading only one commodity.

Sharpe Ratio

The Sharpe ratio is a relative measure of return to risk, and is calculated by dividing mean monthly returns by standard deviation of monthly returns. Sharpe ratio results show that trading performance decreases as reversion parameters decrease, and further suggests that futures prices revert toward fundamental value. Averaged across commodities, Table 2.1 for the large reversion parameter shows the Sharpe ratio to be 0.12, then decreases to 0.08 for the intermediate parameter, and decreases to 0.05 for the small reversion parameter. These results are consistent across commodities, with decline in performance being most pronounced for oats as discussed above.

Minimum and Maximum

Minimum and maximum return statistics indicate that trading performance declines as the reversion parameter is decreased, which supports the hypothesis that prices revert towards fundamental value. Minimum and maximum monthly returns decrease as reversion parameters are decreased. As well, the reduction in minimum returns is much larger than the reduction in maximum returns and may indicate asymmetry in returns.

Averaged across commodities, minimum monthly returns decrease from -106.6 percent for the large reversion parameter, to -123.8 percent for the intermediate parameter, to -159.0 percent for the small reversion parameter. Maximum monthly returns decrease from 113.4 percent for the large reversion parameter to 109.0 percent for the small reversion parameter.

Oats has more extreme minimum returns than the other commodities studied. For the small reversion parameter oats shows a minimum monthly return of -286.6 percent, while corn, wheat, and canola show minimum returns of -127.4 percent, -99.9 percent, and -122.1 percent, respectively.

Minimum and maximum returns decrease when reversion parameters are reduced more for oats than for the other commodities studied, and appear to be associated with the oats trade that occurred during the high prices of 1988. When reversion parameters are reduced, the maximum return for oats decreases but maximums for the other commodities studied do not. Similarly, the minimum return for oats decreases from -165.7 percent for the large reversion parameter to -286.6 percent for the small reversion parameters, a decrease of 120.9 percent, but minimum returns for the other commodities studied decrease no more than 40 percent from the large reversion parameter to the small reversion parameter. These minimum and maximum returns for oats are associated with the large losing oats trade discussed earlier.

Drawdown

Drawdown is defined as the reduction in equity due to repeated losses, and is measured between new equity highs and subsequent equity lows. Maximum drawdown is the largest of these drawdowns in equity. Table 2.2 presents trading profitability statistics and includes maximum drawdown.

Maximum drawdown is large, even if trades are eventual winners, and indicates that the system may cause traders to lose all of their equity unless they de-leverage their positions. For example, maximum drawdown for corn with the large reversion parameter is $6,275. If corn is priced at three dollars per bushel then investment in initial margin is $600 for one 5000 bushel contract with a four percent margin. Since it is assumed that 25 percent of equity is invested in initial margins, then total equity invested is only $2,400 and is insufficient to cover drawdowns of $6,275.

In order to successfully trade individual commodities, margin investment should be de-leveraged to a level considerably less than the 25 percent assumed in this study. Margin investment may need to be de-leveraged, for example to 10 percent of total equity, to avoid being forced out of positions by margin calls. This de-leveraging would result in a proportional reduction in percentage returns.

Alternatively, this system might be used to successfully trade a diverse portfolio of commodities which have relatively uncorrelated prices. By trading commodities with uncorrelated prices it may be possible to offset losses in some commodities with gains in others and as a result may reduce the amount of equity required to trade this system. By trading a diverse portfolio of many commodities it may even be possible to trade this system without changing the amount of leverage used in this study. However, returns to trading a large portfolio of commodities using this system is not tested in this study.

Trading Profitability Statistics

Table 2.2 shows trading profitability statistics. The average trade length is greater than 200 trading days for all reversion parameters, but tends to decrease when reversion parameters used to generate trades is decreased. This average length of trade is comparable to the number of trading days in a year (approximately 250) and may be related to the amount of time required to clear the commodity market. Production patterns may be unable to change quickly because of asset fixidity, technical knowledge, climate factors, or marketing commitments. Consumers, such as grain processors or livestock producers, may face similar restrictions.

Most trades signaled by this system are short trades, with the percentage of long trades decreasing as the amount of reversion is increased. Averaged across commodities in Table 2.2, the percentage of long trades decreases from 21 percent for the small reversion parameter to six percent for the large reversion parameter. These results indicating positive returns from short trades may be related to previous research indicating the existence of asymmetry in futures markets. Upon review of the results, it appears that equilibrium may be too low for most commodities studied and as a result the system does not generate many long trades. As well, it appears that price does not fall substantially below estimated equilibrium and may suggest that the trading rule could be modified so that entries for long trades are different from entries for short trades, such that the difference required between current futures prices and estimated equilibrium prices is not as large to enter long positions as it is to enter short positions.

Risk aversion may explain the result showing that most trades are short trades. Consumers may prefer to have excess supplies of the commodity available rather than incur the costs of having insufficient supplies. During times of supply shortages, such as those which may occur during drought or frost, buyers may purchase excess supplies to ensure that consumption commitments are met. In the process of purchasing these supplies they may drive up futures prices. This idea of risk aversion may be particularly relevant to buyers of feed grains, such as livestock producers. The cost to store necessary feed grains may be low relative to losses that could occur if they feed inventories were exhausted and producers were forced to prematurely sell their production. Premature sales of their livestock may result in reduced revenue since livestock may be less than optimal market weight, or may disrupt future operations if sales interfere with livestock breeding plans.

Trades indicated by this system are generally winners, and winning percentage increases when reversion parameters are increased. These results provide support for the hypothesis that futures markets revert toward long-term fundamental value. Averaged across commodities, Table 2.2 shows that the winning percentage increases from 73 percent for the small reversion parameter to 100 percent for the large reversion parameter.

Time in the market is low relative to trend-following technical trading systems. Averaged across commodities, Table 2.2 shows that time in the market is 43 percent for the small reversion parameter, and is representative of time in the market for the other signals presented.[5] Since this system is in the market for such a relatively short percentage of time then trading equity can be placed in other investment vehicles such as fixed-income investments or equities while it is out of the market.

Exclusion of Monthly Returns with Neutral Market Position

The trading model is in the market long or short about 43 percent of the time, and is out of the market (market neutral) about 57 percent of the time. Therefore, it may be reasonable to assume that returns should only be computed for the period that the system is in the market (Table 2.3). When it is out of the market, capital would then be used for alternative investments. Excluding returns when the system is not in the market either long or short makes this system more comparable with most technical trading systems, since most technical systems are usually in the market 100 percent of the time.

Results in Table 2.3, which exclude neutral market positions, are similar to those presented in Table 2.1, where all months are included, with some expected differences. The first obvious difference in the two measures is that the mean monthly return for the system is higher than the mean monthly return reported in Table 2.1. Second, the standard deviation of monthly returns is higher than previously discussed, and third, the kurtosis of these results is much lower. These results are expected since the mode of the distribution, zero percent monthly return, is less than the mean and is excluded from results. In general, these results demonstrate that mean and variability of returns is high while the system is in the market, and that performance is moderated considerably by holding a neutral market position.

Summary

The objectives of this study are to test for mean reversion in commodity futures markets based on the level of returns from a long-term fundamental mean reversion fundamental model, and to analyze the variability of these returns. Mean reversion theory suggests that if prices diverge from fundamental value then economic forces will cause futures prices to revert towards fundamental value in the long-term. A trading system may be able to use economic fundamentals to identify mispricing and may be able to earn positive returns when prices revert towards long-term fundamental value. Levels and variability of returns to trading corn, wheat, oats, and canola futures prices are analyzed out of sample over the 1980-1997 period to determine the extent to which futures prices revert to fundamental value in the long-term.

This study uses stocks and usage data in a regression model to determine fundamental equilibrium value. Long trades are signaled if futures prices fall a predetermined amount below estimated fundamental equilibrium value, and short trades are signaled if futures prices rise a predetermined amount above estimated fundamental equilibrium value. Trades are exited when futures prices approach fundamental value

First, results show that futures prices appear to follow a pattern of long-term reversion toward fundamental value, since the long-term mean reversion fundamental model earns positive returns for all commodities studied, with return levels generally consistent across the commodities and the parameters studied. As well, returns tend to increase and variability tends to decrease when reversion parameters are increased.

These results suggest that futures prices sometimes diverge from equilibrium, with positive returns being earned when they return to equilibrium. The movement of prices away from equilibrium may be related to uncertainty of supply and demand conditions, with such price movements occurring when market participants attempt to protect themselves against uncertainty, and may be observed as cycles or overreaction. Prices may revert toward equilibrium in the long-term when market participants are able to make adjustments in production and consumption in order to maximize profits and utility. Since cost of production and prices jointly determine profitability, then cost of production may be an important factor in determining fundamental equilibrium futures prices.

Second, the variability of returns, the high levels of drawdown, and the extreme minimum returns that accompany this system suggest that risks need to be controlled in order to profitably trade this system. This system may be appealing to traders who are able to trade a diverse portfolio of commodities, such as institutional investors, and thus diversify their risk. Alternatively, it may be possible to improve the tradeability of this system by de-leveraging, or in other words, by reducing margin commitments. Lower leverage will reduce the risks associated with this system by reducing variability in proportion to the reduction in leverage without affecting significance of returns, but will correspondingly reduce mean return levels.

Third, trading profitability statistics are consistent with expectations. Trade length is generally greater than 200 trading days, and may be as long as several years. Trade length resembles the number of trading days in a year (approximately 250) and suggests that trading length may be related to the ability of farmers to adjust production levels and clear the commodity market.

Most trades signaled by this trading system are winning trades. The observation of high winning percentages which increase as the amount of reversion required to generate trades increases provides further support for the hypothesis that futures markets may revert towards fundamental value in the long-term.

This trading system generally indicates short positions rather than long positions, and the percentage of short positions tends to increase as reversion parameters are increased. It may be possible to change the trading rule and the definition of equilibrium such that more long trades are generated by the system. This result may be related to other studies suggesting asymmetry in futures markets, and may be related to risk aversion during commodity shortages.

Time in the market for this fundamental system is low. This trading system tends to be in the market approximately 43 percent of the time for the reversion parameters studied. Equity could be invested in other types of securities to further enhance returns while waiting for the next opportunity to enter the futures market.

Fourth, the results of this study may have implications for semi-strong form market efficiency theory which holds that positive returns should not be possible. Results suggest that futures prices sometimes diverge from fundamental values, perhaps because of uncertainty associated with large price movements and inadequate information, such that positive returns may be earned by long-term mean reversion trading systems when prices revert toward fundamental values. The positive returns observed subsequently imply that futures markets may not incorporate all public information into prices in the long-term and may not be semi-strong form efficient. The benefits from using long-term fundamental analysis may not be fully realized by market participants and subsequently they may earn some positive returns by analyzing fundamental information.

Endnotes

[1]Soybeans total use and ending stocks statistics are used to estimate canola equilibrium prices. This substitution is done for three reasons. First, soybeans are the largest oilseed crop produced in the market. Second, canola is a close substitute for soybeans and third, canola disposition data is not readily available.

[2]September soybean futures prices are used as a proxy for the value of the September canola futures contract for the 1973 to December 1980 period. September soybean futures are converted from price per bushel to price per tonne to make it comparable with the canola contract.

[3]Augmented Dickey-Fuller unit root tests were performed on closing futures prices. The hypothesis of unit roots were rejected for canola and corn at the five percent confidence level, was rejected for oats at the one percent confidence level, and was rejected for wheat at the 10 percent confidence level, suggesting that futures prices studied are stationary. Stationarity implies that the mean and variance of the series do not depend on time and hypothesis testing is not subject to bias from random walks in the data. It also suggests that price series do not exhibit trends that can be readily identified.

[4]Changes in demand were expected to have less dramatic effects for positions being rolled over because demand changes occur relatively smoothly compared to changes in supply.

Table 2.1 Monthly Returns from Mean Reversion Fundamental Model, 1980-1997: *Including* Months with Market Neutral Position

Reversion[a]	Commodity	Mean %[b]	Std. Dev.	SR[c]	CV[d]	Min	Max	Skew	Kurt	T-Value
Small	Corn	1.2	23.5	0.05	19.1	-127.4	100.8	-0.3	7.9	0.78
	Wheat	1.9	22.5	0.09	11.7	-99.9	96.4	-0.2	5.4	1.28
	Oats	0.3	32.6	0.01	114.1	-286.6	90.2	-3.0	27.6	0.13
	Canola	1.1	25.8	0.04	22.7	-122.1	148.7	0.0	8.2	0.64
	Average	1.1	26.1	0.05	41.9	-159.0	109.0	-0.9	12.3	0.71[e]
Intermediate	Corn	1.8	21.5	0.08	12.0	-87.4	100.8	0.4	5.9	1.24
	Wheat	2.2	21.3	0.10	9.7	-74.4	96.4	0.6	5.1	1.55
	Oats	1.8	29.8	0.06	16.4	-229.3	106.4	-1.8	17.7	0.91
	Canola	1.9	24.7	0.08	13.1	-103.9	148.7	0.2	8.5	1.11
	Average	1.9	24.3	0.08	12.8	-123.8	113.1	-0.1	9.3	1.20[e]
Large	Corn	3.1	23.7	0.13	7.6	-87.4	100.8	0.5	4.7	1.94**
	Wheat	2.5	22.6	0.11	9.1	-74.4	96.4	0.4	3.1	1.66**
	Oats	3.2	25.9	0.12	8.2	-165.7	107.7	-0.5	11.5	1.82**
	Canola	3.2	24.4	0.13	7.7	-99.0	148.7	0.6	7.7	1.89**
	Average	3.0	24.1	0.12	8.1	-106.6	113.4	0.3	6.7	1.83[e]

*Indicates statistical significance at the 95% confidence level in two-tailed t-tests

**Indicates statistical significance at the 90% confidence level in two-tailed t-tests

[a]Reversion parameter for trading rule with positions entered when current futures prices are 1.0, 1.5, and 2.0 mean squared errors away from equilibrium and exited when current futures prices are 0.6, 0.3, and 0.0 mean squared errors away from equilibrium for Small, Intermediate, and Large reversion parameters, respectively, with equilibrium estimated using stocks to use ratio in an econometric model

[b]Returns from trading are computed by dividing the dollar value gained by the trading capital invested. One quarter of the trading capital is invested in margins, with three quarters set aside for margin calls. For example, if trading gain is $100 and trading capital invested is $1000, return would be 10 percent.

[c]Sharpe Ratio

[d]Coefficient of Variation

[e]These t-values are averages so are not evaluated for statistical significance

Table 2.2 Trading Profitability Statistics from Mean Reversion Fundamental Model, 1980-1997

Reversion[a]	Commodity	Long Trades	Short Trades	Long (%)	Winning (%)	Avg Trade Length (Days)	Time in Market (%)	Avg Profit per Winner ($)	Avg Profit per Loser ($)	Largest Winner ($)	Largest Loser ($)	Maximum Drawdown ($)	Ending Equity[c] ($)
Small	Corn	0	5	0	80	323	35	1,916	-1,600	4,000	-1,600	6,775	8,362
	Wheat	1	7	13	63	221	38	3,823	-813	8,138	-1,350	7,625	19,291
	Oats	5	8	38	69	140	42	556	-569	1,238	-1,150	7,225	3,756
	Canola	0	5	0	80	476	57	1,269	-1,390	3,920	-1,390	3,766	3,976
	Average	1.50	6.25	13	73	290	43	1,891	-1,093	4,324	-1,373	6,348	8,846
Intermediate	Corn	0	3	0	100	608	39	3,642	N/A[b]	5,825	N/A[b]	6,275	13,274
	Wheat	0	3	0	100	522	33	6,421	N/A[b]	9,575	N/A[b]	6,300	22,004
	Oats	2	4	33	100	293	41	1,223	N/A[b]	2,675	N/A[b]	5,625	8,544
	Canola	0	3	0	67	811	59	3,036	-756	4,356	-756	3,766	4,806
	Average	0.50	3.25	8	92	558	43	3,580	N/A[b]	5,608	N/A[b]	5,492	12,157
Large	Corn	0	3	0	100	672	43	5,925	N/A[b]	7,300	N/A[b]	6,275	20,124
	Wheat	0	2	0	100	1127	48	12,094	N/A[b]	18,513	N/A[b]	6,300	26,954
	Oats	1	3	25	100	358	33	2,944	N/A[b]	5,300	N/A[b]	5,000	13,031
	Canola	0	3	0	100	798	58	2,729	N/A[b]	4,996	N/A[b]	3,766	7,628
	Average	0.25	2.75	6	100	739	46	5,923	N/A[b]	9,027	N/A[b]	5,335	16,934

[a]Reversion parameter for trading rule with positions entered when current futures prices are 1.0, 1.5, and 2.0 mean squared errors away from equilibrium and exited when current futures prices are 0.6, 0.3, and 0.0 mean squared errors away from equilibrium for Small, Intermediate, and Large reversion parameters, respectively, with equilibrium estimated using stocks to use ratio in an econometric model

[b]Not available since there were no losing trades for these categories

[c]Beginning equity for corn (5000 bu), wheat (5000 bu), oats (5000 bu), and canola (20 t) were $2424, $2816, $1356, and $1040, respectively

Table 2.3 Monthly Returns from Mean Reversion Fundamental Model, 1980-1997: *Excluding* Months with Market Neutral Position

Reversion[a]	Commodity	Mean %[b]	Std. Dev.	SR[c]	CV[d]	Min	Max	Skew	Kurt	T-Value
Small	Corn	3.4	38.7	0.09	11.4	-127.4	100.8	-0.4	1.2	0.80
	Wheat	4.8	35.2	0.14	7.3	-99.9	96.4	-0.4	0.6	1.31
	Oats	0.6	46.5	0.01	72.8	-286.6	90.2	-2.2	12.4	0.14
	Canola	1.9	33.5	0.06	17.5	-122.1	148.7	-0.1	3.7	0.64
	Average	2.7	38.5	0.07	27.3	-159.0	109.0	-0.7	4.5	0.72[e]
Intermediate	Corn	4.5	33.8	0.13	7.5	-87.4	100.8	0.0	0.6	1.25
	Wheat	6.6	36.5	0.18	5.6	-74.4	96.4	0.0	-0.2	1.57
	Oats	3.9	44.5	0.09	11.5	-229.3	106.4	-1.4	6.8	0.87
	Canola	3.2	32.1	0.10	10.1	-103.9	148.7	0.1	3.9	1.11
	Average	4.5	36.7	0.12	8.7	-123.8	113.1	-0.3	2.8	1.20[e]
Large	Corn	7.0	35.3	0.20	5.0	-87.4	100.8	0.0	0.5	1.97**
	Wheat	5.2	32.3	0.16	6.3	-74.4	96.4	0.1	0.0	1.67**
	Oats	8.3	42.8	0.19	5.2	-165.7	107.7	-0.7	3.0	1.72**
	Canola	5.4	31.6	0.17	5.9	-99.0	148.7	0.3	3.4	1.90**
	Average	6.5	35.5	0.18	5.6	-106.6	113.4	-0.1	1.7	1.82[e]

*Indicates statistical significance at the 95% confidence level in two-tailed t-tests

**Indicates statistical significance at the 90% confidence level in two-tailed t-tests

[a]Reversion parameter for trading rule with positions entered when current futures prices are 1.0, 1.5, and 2.0 mean squared errors away from equilibrium and exited when current futures prices are 0.6, 0.3, and 0.0 mean squared errors away from equilibrium for Small, Intermediate, and Large reversion parameters, respectively, with equilibrium estimated using stocks to use ratio in an econometric model

[b]Returns from trading are computed by dividing the dollar value gained by the trading capital invested. One quarter of the trading capital is invested in margins, with three quarters set aside for margin calls. For example, if trading gain is $100 and trading capital invested is $1000, return would be 10 percent.

[c]Sharpe Ratio

[d]Coefficient of Variation

[e]These t-values are averages so are not evaluated for statistical significance

CHAPTER 3

LONG-TERM MEAN REVERSION RETURNS AND TECHNICAL ANALYSIS IN COMMODITY FUTURES MARKETS

Introduction

Mean reversion theory states that prices may move away from equilibrium but return to equilibrium over time. This theory is similar to the investment advice to "buy low and sell high" that is familiar to institutional and individual investors. Some evidence of this mean reverting price pattern has been found in commodity markets, but returns to such an investment strategy have not been widely analyzed. Therefore, returns from a long-term mean reversion technical futures trading system are examined in this study in order to provide further empirical evidence.

Agricultural commodities such as grains may be of particular interest to a long-term mean reversion trading system because of the relatively inelastic supply and the long time lag that exists between production decisions and harvest. Mean reversion may be more obvious in these markets because of time lags in supply and demand response to changes in price levels. An improved understanding of the market behavior of these commodities may help buyers and sellers to make appropriate trading decisions, particularly in the long-term, and may help traders to improve their strategies.

Desire for alternative long-term investment vehicles, well known by terms such as "value investing" and "contrarian investing," has increased considerably. Long-term mean reversion futures trading systems may satisfy some of this desire for alternative long-term investments. Long-term technical trading systems are cost efficient in the sense that they have much lower transaction costs than shorter-term technical trading systems. As well, the increased use of computer driven short-term trend-following systems may be removing some of the profitable trends from the various commodity markets. This may increase the desire for alternative trading systems such as mean reversion trading systems.

This study develops a long-term mean reversion model, and because it uses past prices, it can be considered to be a technical trading system. If positive returns can be earned by this system then it may provide further evidence of mean reversion. The results of this study may also suggest possible explanations as to the source of mean reversion.

Therefore, the objectives of this study are to 1) test for long-term mean reversion in commodity futures markets for grains based on the level of returns from a long-term technical mean reversion model, and 2) analyze the variability of these returns.

Past Research

The movement of prices back from extreme levels toward a central tendency is generally known in asset pricing literature as mean reversion. Mean reversion theory states that if prices move away from their mean then economic factors are expected to eventually return them to their mean. If a price series is mean reverting then a somewhat predictable pattern may exist within the series and future price movements might be identified from past prices. If future price movements can be identified from past prices with some accuracy then profitable trading strategies might be developed.

The cobweb model may describe pricing patterns in agriculture. In the cobweb model, supply and demand schedules are inelastic due to consumption and production habits and other factors so that relatively small changes in supply or small changes in demand may result in relatively large changes in price. As well, there is a lag between the time when farmers make production decisions, and the time when harvest is completed and supplies are determined. The lag in production may result in short-term overproduction or underproduction and may cause large changes in price because supply and demand schedules are inelastic. In the long run as producers and consumers adjust supply and demand schedules to achieve economic equilibrium, prices may move around equilibrium in a pattern similar to that proposed by mean reversion theory.

These markets may be susceptible to large price movements because supply and demand schedules for agricultural commodities are relatively inelastic, which may cause large price movements and may result in mispriced commodities. The trading strategy proposed here enters the market when prices diverge from mean levels and exits the market when prices revert to mean levels in a manner consistent with mean reversion. If mispricing does exist then this system may be able to earn positive returns.

Long-term mean reversion is well-researched in equity markets, with De Bondt and Thaler (1985, 1987) making some of the early contributions. Fama and French (1988) show that autocorrelation of returns is weak for short-term investment horizons, but becomes negative for two year returns, and may account for 25% to 40% of variation in three to five year returns, suggesting stock market predictability. Other articles testing for long-term mean reversion in stock markets include Poterba and Summers (1988), Chiang, Liu, and Okunev (1995), McQueen (1992), Cutler, Poterba, and Summers (1991), and Cecchetti, Lam, and Mark (1990).

Some research of mean reversion in commodity prices exists though it is less comprehensive than that of stock prices. Bessimbinder, Coughenour, Seguin, and Smoller (1995) examine the term structure of futures markets to determine if mean reversion is present in equilibrium. They find that the slopes of the term structure and the elasticities they imply provide strong evidence of mean reversion in agricultural commodities, as well as metals and oil, but only weak evidence for financial assets. More recently, Schwartz (1997) models the futures prices of copper, gold, and oil using mean reversion and shows that copper and oil are strongly mean reverting but gold is not. Cutler, Poterba, and Summers (1991) show that asset spot prices are positively correlated over short horizons but are negatively correlated over long horizons. Allen, Ma, and Pace (1994) examine price movements fifteen days after significant events and show that over-reaction may exist in agricultural commodity spot prices even in the short-term. These studies provide some evidence that commodity markets may be mean reverting.

Park and Switzer (1996) develop a trading system to try to profit from mean reversion of interest rate term premiums. They enter futures positions when Treasury note spreads differ from historical spreads, with the expectation that the spread will return to historical levels and the system will earn positive returns. Their research shows that it may be possible to earn positive returns using mean reversion to trade interest rate futures contracts, and implies that it may be possible to successfully trade other commodities using mean reversion theory. The study proposed here uses a mean reversion trading strategy similar to the one used in their research, as it enters long positions if prices are low relative to historical prices and enters short positions if prices are high relative to historical prices, but agricultural commodities are studied rather than interest rate spreads.

Jackson, Zulauf, and Irwin (1991) investigate mean reversion of futures prices in agricultural commodities and show several interesting results. Their research shows that mean reversion appears to exist for horizons of three and six months, but that horizons of one month do not appear to be mean reverting. They suggest that mean reversion of commodity futures prices may be related to the cost of production. They develop mean reverting trading strategies that earn positive returns and suggest that mean reversion may be the reason that selective hedging studies show improved returns over unhedged systems. Their research appears to indicate that mean reversion exists in agricultural futures markets, but their results are sensitive to the period studied.

Studies of long-term mean reversion with relatively few observations have been criticized for their low statistical power. Many studies provide some evidence that long-term mean reverting price patterns occur in asset prices but they are unable to confirm the finding with high levels of significance. Due to the nature of long-term mean reversion research the limitation of small samples is unlikely to be overcome, but this study may expand mean reversion literature and may provide further evidence to suggest the extent to which mean reversion exists in commodity markets.

The results of these studies provide reasons to believe that mean reversion may exist in commodity markets. However, the fact that a limited amount of data is available for long-term tests of mean reversion in commodity futures markets clearly indicates that further research of mean reversion in commodity futures markets is needed.

This study assumes, given the above research, that mean reversion may exist in agricultural commodity futures markets and tests whether mean reversion can be used to develop a trading strategy that earns positive returns. If a trading system can be developed that earns positive returns then this study may provide further evidence to support the hypothesis that mean reversion exists in futures markets.

Data and Procedure

Data used in this study consists of agricultural commodities. In particular, grains are used because they generally have relatively inelastic supply and inelastic demand schedules. They may exhibit relatively high long-term price variation in a manner consistent with mean reversion compared to other commodities that are less inelastic. As well, they have extensive and readily available futures price data series. Futures contracts examined in this study are May oats, September corn, May wheat, and September canola,[1] with these months used because they coincide with the end of the crop year.

Oats, corn, and wheat trade on the Chicago Board of Trade while canola trades on the Winnipeg Commodity Exchange. The wheat and corn price series begin in 1968, oats begins in 1974, and the price series used for canola begins in 1973. Daily opening and closing futures prices are used in this study and are provided by Technical Tools, Inc.

Equilibrium Model

This study defines equilibrium price to be the long-term mean of daily closing prices. The equilibrium price is calculated using all closing prices available from the beginning of the time series up to but not including the most recent closing price available prior the day of trading. Equilibrium is calculated daily using existing data from all past years, plus the new data available from the most current period.

This definition of equilibrium is chosen because it is simple to compute, can be incorporated into a trading system with relative ease, and is expected to capture long-term market characteristics. This model may not be as sensitive to short-term fundamental changes as models that use shorter sample periods, but should adapt to long-term changes. As well, a trading system that incorporates a simple model of equilibrium may be helpful in providing a more concise explanation of mean reversion in commodity prices.

Trading Rule

Define equilibrium as long-term mean historical price, and

Enter:

(1) *Go long (buy)* when the current daily closing futures prices *fall below* equilibrium, e.g. *fall* one standard deviation *below* equilibrium.

(2) *Go short (sell)* when current daily closing futures prices *rise above* equilibrium, e.g. *rise* one standard deviation *above* equilibrium.

Exit:

(3) *Exit* above positions when the current futures prices *return towards* equilibrium, e.g. within 0.6 standard deviations of equilibrium.

(4) Market positions may be long, short, or neutral (out of the market).

Consider the following example in order to understand the trading rule operation. Suppose September corn futures have an equilibrium of $2.50 per bushel and a standard deviation of 0.4, and suppose entries are generated when current daily closing futures prices are one standard deviation from equilibrium and exits are generated when current daily closing futures prices are 0.6 standard deviations from equilibrium. Then short positions are entered if futures prices rise $0.40 above equilibrium to reach $2.90 per bushel, and are exited if futures prices fall to within $0.24 of equilibrium, or $2.74 per bushel. Similarly, long positions are generated when current futures prices fall $0.40 below equilibrium to reach $2.10 per bushel, and are exited when current futures prices rise to within $0.24 of equilibrium, and reach $2.26 per bushel.

If prices are normally distributed then approximately 68 percent of all observations are contained within one standard deviation from the mean, approximately 87 percent of all observations are contained within 1.5 standard deviations from the mean, and approximately 95 percent of all observations are contained within 2.0 standard deviations from the mean. This idea suggests that the difference between current futures price and calculated equilibrium futures price might be related to the standard deviation of historical prices such that this difference could be used to forecast the direction of the market, with the magnitude of this difference being related to the probability of making a correct forecast. In other words, the further that prices diverge from the mean the higher the probability that prices will moderate toward the mean in the future, and the lower the probability that prices will become even more divergent.

Trading Rule Mean Reversion Parameters

Long-term mean reversion is tested by observing three sets of trading results produced by three alternative mean reversion parameters for the trading rule. The *large* reversion parameter is defined as market entry at 2.0 standard deviations from equilibrium and market exit at equilibrium. The *intermediate* reversion parameter is defined as market entry at 1.5 standard deviations from equilibrium and market exit at 0.3 standard deviations from equilibrium. The *small* reversion parameter is defined as market entry at 1.0 standard deviation from equilibrium and market exit at 0.6 standard deviations from equilibrium.

Trading Model

The system is designed in such a manner that traders could implement it. Mechanical trading procedures and procedures used for computing returns are similar to procedures used by large commodity funds. Trading commences one year prior to delivery on the 1980 futures contract and ends on December 31, 1997, allowing for approximately 18 ½ years of out of sample trading results, with trades generated using closing prices and executed on the next day's opening prices. The 1980 contract is selected as the starting point because all commodities being studied have a considerable amount of data (five years or more) available prior to the 1980 contract. The data available prior to the 1980 contract is used in sample to calculate initial equilibrium and initial standard deviation.

Open positions are rolled over from contracts in one contract year into contracts with the same delivery month in the following contract year. Rolling over open positions occurs on the 15th day, or the next available trading day, of the month preceding the delivery month. Rolling over open positions at this time helps to avoid problems associated with liquidity, squeezes, or forced acceptance of delivery that may occur as the delivery date approaches.

Transaction costs, including brokerage fees and pricing slippage, are assumed to be $25 per trade or $50 for a round-turn. Since this system is expected to trade rather infrequently, brokerage fees and slippage are expected to be minimal. Initial margins used are consistent with historical levels. Twenty-five percent of equity is invested in initial margins, the remaining 75% is set aside for margin calls. This leaves equity available to cover margin calls so that the system is never forced out of a position due to margin calls. Monthly percentage returns are then computed for the 18 year period from Jan. 1, 1980 to Dec. 31, 1997 for each commodity.

Results

Mean Return Levels

Mean reversion returns are computed for three alternative parameters, large, intermediate, and small, in order to examine whether returns are positive and mean reversion exists (Table 3.1). For the large mean reversion parameter, positions are entered when current futures prices are two standard deviations away from equilibrium and are exited when current futures prices are equal to equilibrium, with equilibrium defined as the long-term mean of daily prices. Returns for the large mean reversion parameter are positive for all four commodities, with 2.6 percent average monthly return over the four commodities. This large mean reversion parameter also has the highest average return of the three reversion parameters tested. Mean monthly returns are statistically significant at the five percent level for corn and wheat, and are significant for canola at the ten percent level.

For the intermediate mean reversion parameter, positions are entered when current futures prices reach 1.5 standard deviations away from equilibrium then are exited when current futures prices revert back to 0.3 standard deviations away from equilibrium. Monthly returns are positive for the intermediate parameter but generally are lower than those for the large parameter, averaging 1.9 percent monthly return across the four commodities. Statistical significance is reduced, with corn being significant at the ten percent level and no commodities being significant at the five percent level.

For the small mean reversion parameter, positions are entered when current futures prices reach 1.0 standard deviations away from equilibrium and are exited when current futures prices revert to 0.6 standard deviations away from equilibrium. As with the large and intermediate parameters, mean monthly returns for the small mean reversion parameter are positive for the four commodities studied. The average monthly return over the four commodities is 1.2 percent, which is the lowest average return of the three levels of reversion tested. None of the returns are significant when the small parameter is used.

Results show that it may be possible to use a mean reversion trading strategy to earn positive returns, and suggest that mean reversion exists in futures markets. The observed returns are positive, and in some cases returns are statistically significant implying that they compensate for risk. As well, returns tend to increase as mean reversion parameters are increased, which is consistent with implications of mean reversion theory and provides further evidence to support the hypothesis that mean reversion exists in futures markets. These results are generally consistent with findings by Jackson, Zulauf, and Irwin (1991).

The system earns return levels similar to those earned by traditional trend-following technical trading systems. Traditional trend-following technical trading systems have been shown to earn some positive returns in a number of different studies. Lukac and Brorsen (1990) show mean monthly returns of 1.2 percent for corn, 0.5 percent for soybeans, and -2.2 percent for wheat to trend-following technical trading systems over the 1976 to 1986 period. Their results for trend-following technical trading systems are not directly comparable but they are generally below the returns observed in this study.

Returns for oats are not significant for any of the reversion parameters tested. It appears the system makes one oats trade that initially results in considerable losses but later recovers. The losses associated with this one particular trade appear to result in insignificant returns to oats trading. The observation of this one large losing oats trade demonstrates the risk associated with trading only one commodity and no diversification using this system.

Some of the long-term trading profits from this mean reversion system may occur because of a partial failure to incorporate expected long-term response to short-term economic shortages/surpluses into distant futures prices. Distant futures prices appear closely related to nearby market conditions, and may not fully reflect the expected alleviation of economic shortages/surpluses in the long-term as economic forces attempt to clear the commodity market. For example, short trades tend to be entered during times of tight supplies such as drought or frost, then are exited when these supplies become more plentiful. This explanation of trading profits suggests that the adaptive expectations hypothesis might be more commonly used to price the commodities studied than the rational expectations hypothesis, since the recent past appears to be more evident in commodity prices than are long-term future expectations.

Overall, mean return results suggest that mean reversion is present in futures markets, as evidenced by positive returns. As well, monthly returns become larger as the size of the mean reversion parameter becomes larger. Mean monthly return levels may be relatively conservative and may somewhat understate actual returns for two reasons. First, returns from investing margin requirements and equity in T-bills are not included in returns. Second, this system is in the market for only a limited amount of time. The rest of the time, while the system is out of the market, funds could be invested in other vehicles such as T-bills, bonds, or stocks, and earn positive returns on average over the long-term.

Standard Deviation

Variability of returns also provides evidence to support the hypothesis that mean reversion exists in futures markets. This is because variability of returns appears to decrease as mean reversion parameters are increased. Table 3.1 shows that variability of monthly returns for the large mean reversion parameter has average standard deviation levels across commodities of 21.4. Standard deviation of monthly returns increases to 22.1 for the intermediate parameter and increases further to 25.1 for the smallest level of mean reversion parameter.

Standard deviations of returns are comparable to results presented by Lukac and Brorsen (1990) for traditionally traded technical systems, which show standard deviations of about 20, 25, and 23 for corn, soybeans, and wheat respectively. Although the long-term technical trading system examined in this study generates trades based on analysis methods that differ from those of traditional trend-following technical systems, the observation of somewhat similar standard deviations of returns is interesting.

Sharpe Ratio

The Sharpe ratio used here is a measure of risk-adjusted returns and is calculated by dividing mean monthly returns by the standard deviation of monthly returns. The larger Sharpe ratios (e.g. higher return to risk) found here and associated with the large mean reversion parameter are consistent with the hypothesis that futures prices may be long-term mean reverting. Averaged across commodities, Table 3.1 shows the Sharpe ratio is 0.13 for the large parameter, then decreases to 0.09 for the intermediate parameter, and decreases to 0.05 for the small parameter.

With the exception of oats, Sharpe ratios are consistent across commodities which suggests that mean reversion is characteristic of the commodities studied. The Sharpe ratio for oats is approximately one-half of the ratios for the other commodities studied, and is the combined result of oats having relatively low returns and relatively high standard deviations. Again, the relatively low performance for oats is primarily due to one large losing trade, and illustrates the risk associated with this trading system for only one commodity.

Minimum and Maximum

Minimum and maximum return statistics suggest that trading performance improves when larger mean reversion parameters are used to generate trades. Minimum returns improve considerably while maximum returns are about the same when larger parameters are used. As well, the most extreme minimum monthly returns and the most extreme maximum monthly returns occur when the small reversion parameter is used to generate trades.

Minimum monthly returns for oats are considerably more extreme than minimum returns for the other three commodities. Oats exhibits minimum monthly returns of -229.3 percent, -247.6 percent, and -334.1 percent for the largest, intermediate, and smallest levels of mean reversion tested, respectively, while the other commodities studied tend to exhibit minimum monthly returns near -100 percent. These extreme returns again are the result of the one large losing oats trade discussed above, which indicates the relatively high level of risk that may be associated with trading only one commodity using this system. This result is typical of many commodity trading systems, which typically require a portfolio of commodities to be traded in order to diversify risk away sufficiently. Maximum monthly returns are generally consistent across the commodities studied.

Overall, minimum and maximum returns observed here are similar to those of other typical trend following technical trading systems.

Drawdown

Drawdown is defined as the reduction in equity due to repeated losses and is measured between new equity highs and subsequent equity lows. Maximum drawdown used here is the largest of these drawdowns in equity, and can be thought of as "worst case" of losses. It provides another measurement of variation in monthly returns and helps to describe the possibility of a trader losing all of their equity. Table 3.2 illustrates trading profitability statistics for all entries and exits studied and include maximum drawdown.

Maximum drawdown results indicate that the system may not have sufficient equity available to cover margin calls due to repeated consistent losses. For example, maximum drawdown for corn is $4,050 for the large mean reversion parameter. If corn is priced at $3.00 per bushel, then margin investment is $600 for one 5,000 bushel contract, given a four percent margin requirement. The $600 dollar investment is equal to 25 percent of total equity as assumed in this study, so the total investment required is $2,400 for corn futures. This $2,400 invested is insufficient to meet $4,050 loss.

This system, like most trading systems, is unlikely to be tradeable for individual commodities because of large individual drawdowns in equity. Instead, it would be tradeable only for a portfolio of commodities because a portfolio reduces overall drawdown through diversification. For example, while one commodity is suffering negative returns and drawdowns others will be earning positive returns to offset these drawdowns. One problem with trading only individual commodities is that trades may be long-term winners and may earn statistically significant returns but even such winning trades exhibit large short-term drawdowns in equity before the trades are completed. These short-term drawdowns may bankrupt the system in the short-term even if long-term returns are expected to be positive, and may make trading the system difficult.

In order to improve the mean reversion trading model the percentage of capital invested in margins may need to be de-leveraged from the assumed 25 percent of total capital, to 10 percent of total capital, for example, in order to comfortably meet margin calls. De-leveraging margin investment to 10 percent of total equity would allow the system to meet margin calls of up to $6,000, which is well beyond the $4,050 level of drawdown illustrated in the above example. Of course, returns would be reduced by de-leveraging but risk of going bankrupt would also be reduced. In this de-leveraging example, monthly returns would be reduced from 2.2 percent to approximately 0.9 percent.

Alternatively, trading a well diversified portfolio of 20 or 30 commodities may be an alternative to substantial de-leveraging, because it would not reduce returns. By diversifying a portfolio, less de-leveraging is required and therefore higher returns could be earned. By trading a large portfolio similar to that constructed by Lukac and Brorsen (1990), variability of returns may be uncorrelated and as a result losses on some commodities may be offset by gains in other commodities. Trading such a portfolio would reduce the risk of large drawdown, so this system could be more practical and useful.

Trading Profitability Statistics

Table 3.2 shows a number of statistics for the trading system. Average trade length is greater than 200 trading days for all mean reversion parameters tested and is comparable to the number of trading days in a year, which is about 250 days. In other words, trades are held for about one year on average. Oats shows average trade lengths of less than 200 days for the small reversion parameter. However, positions are held for a long period of time relative to traditional trend-following technical systems, which may range roughly from 10 to 100 days depending on parameters and systems used. This mean reversion system holds positions for an extended length of time, and may be related to the amount of time required to clear the commodity market from large supplies.

Most trades generated by this system are short trades, and the percentage of short trades increases as reversion parameters are increased. One hundred percent of trades for corn, wheat, and canola are short trades for the large reversion parameter. This result suggests that prices rise far above equilibrium but do not fall as far below equilibrium. This may be related to results of other studies which have found evidence of asymmetry in commodity markets.

Time in the market is relatively low, when averaged across commodities. The system is in the market 37 percent of the time when the small mean reversion parameter is used to generate trades and is in the market 33 percent when the large mean reversion parameter is used. This system is in the market much less than trend-following technical trading systems, which are often in the market as high as 100 percent of the time.

The percentage of winning trades is generally high and tends to increase as mean reversion parameters are increased. Averaged across commodities, winning percentage increases from 81 percent for the small parameter, to 100 percent for the large parameter. This long-term mean reversion trading system appears to be relatively accurate in identifying winning trades and further suggests that mean reversion exists in futures markets.

This winning percentage is considerably higher than winning percentages of trend-following technical trading systems, since trend-following systems typically have winning percentages near 30 or 40 percent. The dissimilarity of this mean reversion technical trading system from widely traded trend-following technical systems may make it attractive for diversification of commodity trading portfolios.

Exclusion of Monthly Returns with Neutral Market Position

The trading system discussed so far in Tables 3.1 and 3.2 both *include* market neutral positions. However, it is only in the market (long or short) about 35 percent of the time. The rest of the time it is out of the market (market neutral), which is about 65 percent of the time. It may be reasonable to assume that returns should be computed only for the period while the system is in the market (Table 3.3) because capital would be used for alternative investments when it is out of the market. Results that *exclude* returns when the system holds a neutral market position (neither long nor short) are more comparable with typical trend-following technical trading systems since most typical trend-following systems generally do not hold neutral market positions for extended periods (Table 3.3).

Results *excluding* neutral market positions in Table 3.3 generally are similar to results in Table 3.1, except returns are considerably higher. Averaged across commodities for the large mean reversion parameter, mean monthly returns are 7.4 percent and standard deviations are 36.5 when neutral positions are excluded, compared to 2.6 percent and 21.4 when neutral positions are included.

Summary

The objectives of this study were to analyze the level and variability of returns from a futures trading system that uses a long-term mean reversion technical model. The system enters long positions when current futures prices fall a predetermined number of standard deviations below historical mean price levels, and enters short positions when current futures prices rise a predetermined number of standard deviations above historical mean price levels. The system generates exits when current futures prices approach historical mean price levels. Three alternative mean reversion parameters (small, intermediate, and large) are used to calculate three corresponding sets of returns. Out of sample trading performance is analyzed over the 1980 to 1997 period for corn, wheat, oats, and canola futures contracts.

First, the hypothesis that long-term mean reversion may exist in futures markets is supported by the results of this study. Results indicate that this mean reversion trading system would have earned positive returns from trading. Monthly returns average 2.6 percent across commodities for the large mean reversion parameter and average 1.2 percent for the smallest mean reversion parameter. Returns tend to increase and variability statistics tend to decrease when the mean reversion parameter is increased, and returns become statistically significant when large mean reversion parameters are used to generate trades. These results suggest that returns to this system adequately compensate for risk and also suggest that it has some market timing ability. As well, results are generally consistent across the commodities studied which strengthens the evidence that long-term mean reversion exists in futures markets.

Mean and variability of returns to this trading system are similar to mean and variability of trend-following technical trading systems. The mean reversion system in this study earns monthly returns of 2.2 percent for corn, 3.3 percent for wheat, 2.2 percent for oats, and 2.8 percent for canola when large mean reversion parameters are used, while Lukac and Brorsen (1990) show monthly returns to trend-following technical trading systems of 1.2 percent for corn, 0.5 percent for soybeans, and -2.2 percent for wheat.

A second result of this study is that the mean reversion system has high variability in returns and large drawdowns in equity that may discourage the use of this system for trading individual commodities, unless the system is traded with relatively low leverage levels. However, in practice this system would likely be used to successfully trade a large portfolio of well diversified commodities as constructed by Lukac and Brorsen (1990) in order to limit drawdown. This is because returns to individual commodities in a well diversified portfolio may be uncorrelated or negatively correlated so that losses in some commodities may be offset by gains in other commodities. Alternatively, de-leveraging the system by investing less money in margins may be useful since it would reduce drawdowns in equity, and therefore reduce the risk of trading this long-term mean reversion trading system.

A third result is that trading statistics are generally consistent with expectations. Average trade length is greater than 200 trading days, and is relatively long as expected, likely because of relatively inelastic supply and demand. The system tends to generate winning trades with winning percentages ranging from 81 percent to 100 percent which is higher than most trend-following systems, which typically have winning percentages of 30 percent to 40 percent. As well, the mean reversion system discussed here is in the market generally much less than 50 percent, while most trend-following systems are in the market for nearly 100 percent of the time.

Finally, returns may be somewhat understated. Returns to capital set aside for investments in T-bills are not considered in this study, which would have increased returns. As well, the mean reversion system is neutral and out of the market much of the time. During these times equity may be invested in instruments other than futures markets, which would further increase returns on average over the long-term.

This is one of the first studies to use a long-term mean reversion technical trading system, and grain commodities were used because they have relatively inelastic supply and demand, which may be expected to have long-term mean reversion in price. However, future research should include a wider portfolio of commodities from different groups such as energy, currency, financials, and metals in order to provide more evidence regarding mean reversion in commodity futures markets.

Endnotes

[1]Actual data for the September canola futures contract commences in December 1980 and runs through to December 31, 1997. September soybean futures prices are used as a proxy for the September canola futures contract for the 1973 to December 1980 period. This is because a reliable canola series was unavailable during this period. Soybeans are the best alternative data for this period, since soybeans and canola have very highly correlated prices due to their close underlying oil and meal substitutability.

Table 3.1 Monthly Returns from Mean Reversion Technical Model, 1980-1997: *Including* Months with Market Neutral Position

Reversion[a]	Commodity	Mean %[b]	Std. Dev.	SR[c]	CV[d]	Min	Max	Skew	Kurt	T-Value
Small	Corn	0.9	21.7	0.04	25.2	-87.4	130.7	1.1	9.8	0.59
	Wheat	1.4	19.4	0.07	14.1	-99.9	96.4	0.0	10.4	1.06
	Oats	0.6	34.8	0.02	57.7	-334.1	78.9	-4.2	38.7	0.26
	Canola	1.8	24.6	0.07	13.5	-122.1	148.7	0.4	9.2	1.08
	Average	1.2	25.1	0.05	27.6	-160.9	113.7	-0.7	17.0	0.75[e]
Intermediate	Corn	2.3	18.0	0.13	7.9	-87.4	100.8	1.0	10.5	1.89**
	Wheat	1.7	16.8	0.10	9.7	-91.6	96.4	0.7	11.9	1.54
	Oats	1.5	28.7	0.05	18.7	-247.6	78.9	-3.0	26.9	0.80
	Canola	2.0	24.9	0.08	12.2	-99.0	148.7	0.4	7.4	1.20
	Average	1.9	22.1	0.09	12.1	-131.4	106.2	-0.2	14.2	1.35[e]
Large	Corn	2.2	15.0	0.15	6.8	-59.4	85.1	1.4	10.4	2.19*
	Wheat	3.3	20.4	0.16	6.2	-74.4	78.5	0.3	4.1	2.43*
	Oats	2.2	28.0	0.08	12.9	-229.3	106.4	-2.2	22.8	1.16
	Canola	2.8	22.2	0.13	8.0	-82.7	148.7	1.3	10.1	1.82**
	Average	2.6	21.4	0.13	8.5	-111.4	104.7	0.2	11.9	1.90[e]

*Indicates statistical significance at the 95% confidence level in two-tailed t-tests

**Indicates statistical significance at the 90% confidence level in two-tailed t-tests

[a]Reversion parameter for trading rule with positions entered when current futures prices are 1.0, 1.5, and 2.0 standard deviations away from equilibrium and exited when current futures prices are 0.6, 0.3, and 0.0 standard deviations away from equilibrium for Small, Intermediate, and Large reversion parameters, respectively, with equilibrium defined as the long-term mean of historical futures prices

[b]Returns from trading are computed by dividing the dollar value gained from trading by the total trading capital invested. One quarter of the trading capital is invested in margins, with three quarters set aside for margin calls. For example, if trading gain is $100 and trading capital invested is $1000, return would be 10 percent.

[c]Sharpe Ratio

[d]Coefficient of Variation

[e]These t-values are averages so are not evaluated for statistical significance

Table 3.2 Trading Profitability Statistics from Mean Reversion Technical Model, 1980-1997

Reversion[a]	Commodity	Long Trades	Short Trades	Long (%)	Winning (%)	Avg Trade Length (Days)	Time in Market (%)	Avg Profit per Winner ($)	Avg Profit per Loser ($)	Largest Winner ($)	Largest Loser ($)	Maximum Drawdown ($)	Ending Equity[c] ($)
Small	Corn	2	4	33	80	223	25	1,284	-88	3,125	-88	6,838	8,249
	Wheat	0	5	0	80	226	24	3,769	-2,050	7,650	-2,050	10,825	15,716
	Oats	11	8	58	75	107	43	378	-544	913	-725	7,538	4,106
	Canola	1	8	11	89	251	54	678	-730	1,074	-730	2,820	5,137
	Average	3.50	6.25	26	81	202	37	1,527	-853	3,190	-898	7,005	8,302
Intermediate	Corn	0	4	0	100	341	29	3,497	NA[b]	5,275	NA[b]	6,225	16,312
	Wheat	0	2	0	100	439	19	7,513	NA[b]	12,975	NA[b]	7,575	17,791
	Oats	4	5	44	78	216	45	888	-413	2,100	-763	5,950	7,044
	Canola	0	3	0	100	805	58	2,004	NA[b]	3,336	NA[b]	3,766	6,402
	Average	1.00	3.50	11	94	450	38	3,475	NA[b]	5,921	NA[b]	5,879	11,887
Large	Corn	0	2	0	100	395	17	6,263	NA[b]	9,200	NA[b]	4,050	14,899
	Wheat	0	2	0	100	799	34	13,906	NA[b]	20,813	NA[b]	5,050	30,604
	Oats	1	4	20	100	264	31	1,753	NA[b]	3,425	NA[b]	5,625	9,994
	Canola	0	3	0	100	676	49	2,533	NA[b]	4,155	NA[b]	3,766	8,064
	Average	0.25	2.75	5	100	533	33	6,114	NA[b]	9,398	NA[b]	4,623	15,890

[a]Reversion parameter for trading rule with positions entered when current futures prices are 1.0, 1.5, and 2.0 standard deviations away from equilibrium and exited when current futures prices are 0.6, 0.3, and 0.0 standard deviations away from equilibrium for Small, Intermediate, and Large reversion parameters, respectively, with equilibrium defined as the long-term mean of historical futures prices

[b]Not available because there were no losing trades for these categories

[c]Beginning equity for corn (5000 bu), wheat (5000 bu), oats (5000 bu), and canola (20 t) were $2424, $2816, $1356, and $1040, respectively

Table 3.3 Monthly Returns from Mean Reversion Technical Model, 1980-1997: *Excluding* Months with Market Neutral Position

Reversion[a]	Commodity	Mean %[b]	Std. Dev.	SR[c]	CV[d]	Min	Max	Skew	Kurt	T-Value
Small	Corn	2.8	38.8	0.07	13.8	-87.4	130.7	0.5	1.1	0.61
	Wheat	5.3	37.9	0.14	7.1	-99.9	96.4	-0.3	0.8	1.08
	Oats	1.2	47.4	0.02	40.7	-334.1	78.9	-3.1	20.1	0.27
	Canola	3.2	32.7	0.10	10.2	-122.1	148.7	0.2	4.0	1.08
	Average	3.1	39.2	0.08	17.9	-160.9	113.7	-0.7	6.5	0.76[e]
Intermediate	Corn	7.5	32.0	0.23	4.3	-87.4	100.8	0.1	1.3	1.93**
	Wheat	8.9	37.6	0.24	4.2	-91.6	96.4	-0.2	0.2	1.56
	Oats	2.5	44.9	0.06	18.1	-247.6	78.9	-1.7	8.0	0.58
	Canola	3.4	32.3	0.11	9.4	-99.0	148.7	0.2	3.3	1.20
	Average	5.6	36.7	0.16	9.0	-131.4	106.2	-0.4	3.2	1.32[e]
Large	Corn	8.3	32.4	0.26	3.9	-59.4	100.8	0.0	0.7	2.36*
	Wheat	9.6	34.1	0.28	3.5	-74.4	78.5	-0.4	-0.2	2.48*
	Oats	6.1	48.4	0.13	7.9	-229.3	106.4	-1.6	6.7	1.09
	Canola	5.6	31.2	0.18	5.6	-82.7	148.7	0.7	3.6	1.83**
	Average	7.4	36.5	0.21	5.2	-111.4	108.6	-0.3	2.7	1.94[e]

*Indicates statistical significance at the 95% confidence level in two-tailed t-tests

**Indicates statistical significance at the 90% confidence level in two-tailed t-tests

[a]Reversion parameter for trading rule with positions entered when current futures prices are 1.0, 1.5, and 2.0 standard deviations away from equilibrium and exited when current futures prices are 0.6, 0.3, and 0.0 standard deviations away from equilibrium for Small, Intermediate, and Large reversion parameters, respectively, with equilibrium defined as the long-term mean of historical futures prices

[b]Returns from trading are computed by dividing the dollar value gained from trading by the total trading capital invested. One quarter of the trading capital is invested in margins, with three quarters set aside for margin calls. For example, if trading gain is $100 and trading capital invested is $1000, return would be 10 percent.

[c]Sharpe Ratio

[d]Coefficient of Variation

[e]These t-values are averages so are not evaluated for statistical significance

CHAPTER 4

SUMMARY

This study tests for long-term mean reversion in grain futures prices by analyzing levels and variability of returns from long-term mean reversion futures trading rules. In this study, if futures prices are above equilibrium, then the commodity futures are sold, and if futures prices are below equilibrium then the commodity futures are bought. This study uses two different models to calculate equilibrium futures prices. Chapter two uses fundamental analysis of USDA information to determine equilibrium futures prices, while chapter three uses a technical model (past prices) to calculate equilibrium futures prices. The study includes corn, wheat, oats, and canola futures prices over the 1980-1997 period.

Long-term Mean Reversion Returns and Fundamental Analysis in Commodity Futures Markets

The objective of chapter two is to 1) test for long-term mean reversion in commodity futures markets for grains based on the level of returns from a long-term fundamental mean reversion model, and 2) analyze the variability of these returns. The fundamental model used for estimating equilibrium futures prices consists of an annual regression model, which uses the ratio of ending stocks to use as the independent variable and uses closing futures price as the dependent variable. Long (buy) signals are generated when current futures prices are low relative to estimated equilibrium futures price, and short (sell) signals are generated when current futures prices are high relative to estimated equilibrium futures price. Positions are exited when current futures prices moderate and return towards equilibrium.

First, results indicate that futures prices appear to follow a pattern of long-term reversion toward fundamental value. This is because returns from the long-term mean reversion fundamental model are positive for all commodities studied, with return levels generally consistent across the commodities and the parameters studied. As well, returns tend to increase and variability tends to decrease when reversion parameters are increased. The reasons that futures prices sometimes diverge from equilibrium may be due to factors such as supply and demand uncertainty, cycles, or overreaction.

Second, the variability of returns, the relatively high levels of drawdown, and the lower minimum returns that accompany this system suggest that risks need to be controlled in order to profitably trade this system. De-leveraging the system and trading diversified portfolios of commodities may be ways to help control risk.

The results of this study may have implications for semi-strong form market efficiency theory which holds that positive returns should not be possible. The positive returns observed subsequently imply that futures markets may not incorporate all public information into prices in the long-term and may not be semi-strong form efficient. The usefulness of long-term fundamental analysis may not be fully realized by some market participants and this may help explain why the system appears to earn some positive returns by using fundamental information.

Long-Term Mean Reversion Returns and Technical Analysis in Commodity Futures Markets

The objective of chapter three is to 1) test for long-term mean reversion in commodity futures markets for grains based on the level of returns from a long-term technical mean reversion model, and 2) analyze the variability of these returns. The system analyzed in this chapter uses a technical model, the mean of past futures prices, to estimate long-term equilibrium futures prices. Long (buy) signals are generated when current futures prices are low relative to equilibrium, and short (sell) signals are generated when current futures prices are high relative to equilibrium. Exit signals are generated when current futures prices moderate and return towards estimated equilibrium futures prices.

Results show that positive returns are earned by this trading system, and show some returns that are statistically significant so appear to compensate for risk. Trading performance generally improves as increased amounts of reversion are used to generate trades. Levels and variability of returns from this system are similar to levels and variability of returns from traditional trend-following technical trading systems, and suggest that this long-term mean reverting system may be useful for long-term trading decisions.

This system is risky as indicated by drawdown and variation of returns, and may limit the use of this system to large commercial users and commodity funds. These market participants can reduce risk by trading a large portfolio of diversified commodities and by de-leveraging their positions.

Comparison of Performance

This study shows that a profitable trading system can be developed from mean reversion theory for both the fundamental and technical models, and suggests that long-term mean reversion exists in grain futures markets. Statistically significant returns and improved trading performance as the mean reversion parameter increases are results which support the hypothesis that grain futures markets are mean reverting. As well, trading performance is generally consistent across commodities and indicates that the models are relatively robust.

Results indicate that the long-term trading performances of the fundamental model and the technical model are similar. Return levels are similar between the two models, with variability being slightly lower for the technical model. Maximum drawdown is slightly lower for the technical model than for the fundamental model when the large mean reversion parameter is used. The technical model may be more attractive for practitioners than the fundamental model for practical reasons rather than for reasons of performance, since it requires less data than the fundamental model and is easier to maintain.

Both the fundamental model and the technical model appear to earn positive long-term returns, so some information may not be fully incorporated into long-term futures prices. The performance of the fundamental model and the technical model is similar and suggests that the two models share a common factor that permits them to earn some positive returns The fact that the two models use a long-term investment horizon suggests that the investment horizon is important for earning positive returns, and suggests that some information may not be fully incorporated into futures prices in the long-term.

The trading system developed in this chapter may also be of value to long-term rollover hedgers because it could be used to identify long-term market peaks and low points. However, even these traders need to have sufficient margin resources available in order to withstand substantial drawdowns in equity.

Limitations of Research

First, the systems studied generate trades infrequently. Infrequent trading means that there are fewer trades and smaller sample sizes, so less degrees of freedom are available for statistical tests. However, the consistent results shown across commodities does strengthen the evidence supporting the hypothesis that long-term reversion exists in grain futures markets but more commodities should be tested to more fully investigate long-term mean reversion in futures markets.

Second, these results are limited to the data studied. Past returns observed in this study may not be observed in the future if traders begin using long-term mean reversion strategies similar to the ones proposed here, and drive futures prices towards long-term equilibrium. Similarly, the results observed in this study may not be observed for commodities other than the ones tested here.

Suggestions for Future Research

First, the model used to estimate equilibrium could be adjusted so that it is more sensitive to changes in price. This change could be done by excluding historical futures prices, which are no longer representative of present day futures prices, from estimates of equilibrium. Second, the trading rule could be modified so that entry into long positions occurs more frequently, which may be achieved by entering long positions at higher prices (closer to equilibrium futures prices) than is done in this study. As a result, the trading rule for entry into long positions may be somewhat different than the rule for entry into short positions. Third, additional commodities should be studied to determine the extent to which long-term mean reversion is present.

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APPENDIX A

Stocks to Use versus Price

Figure A.1
Oats Stocks to Use versus Price

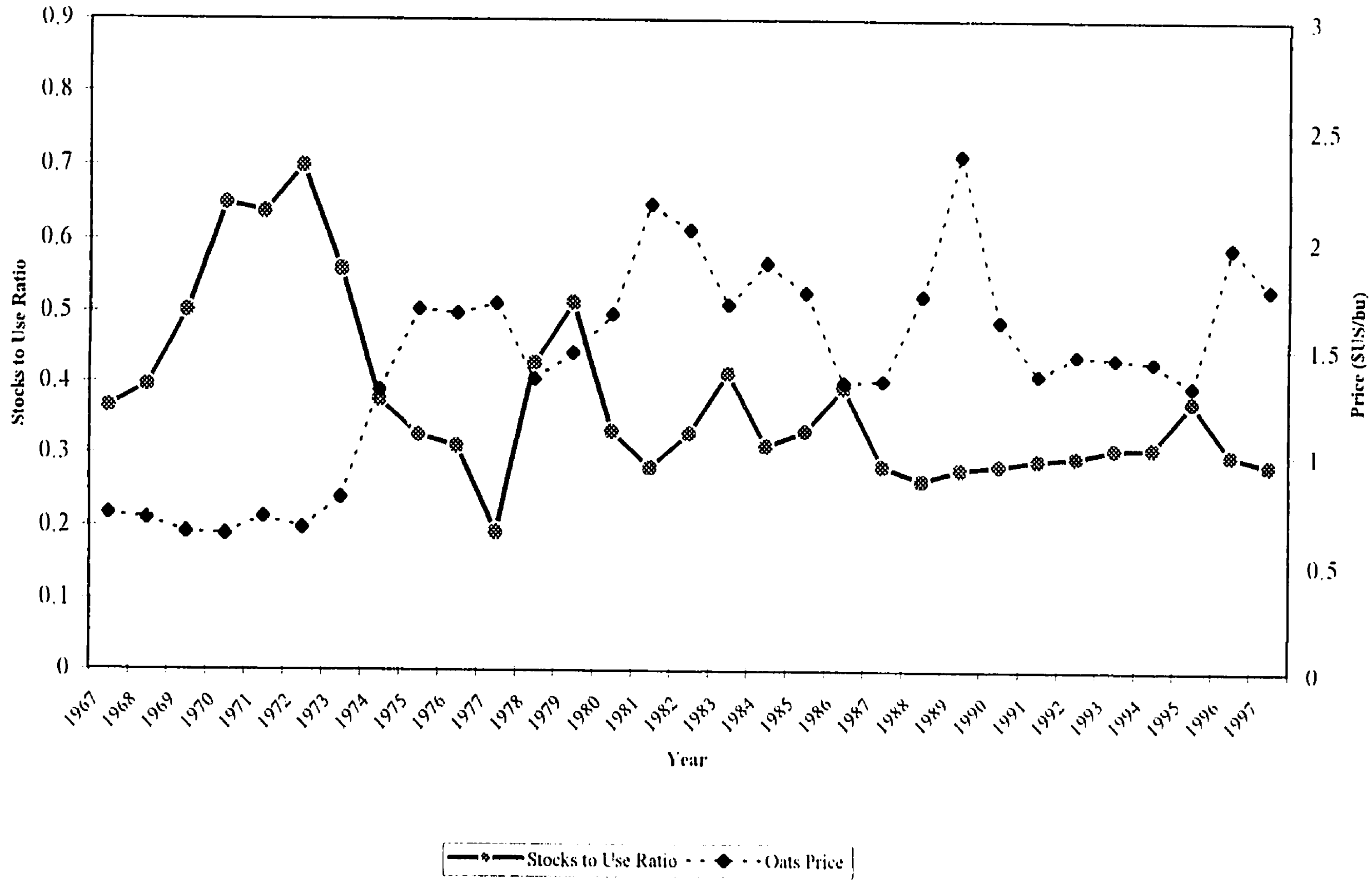


Figure A.2
Corn Stocks to Use versus Price

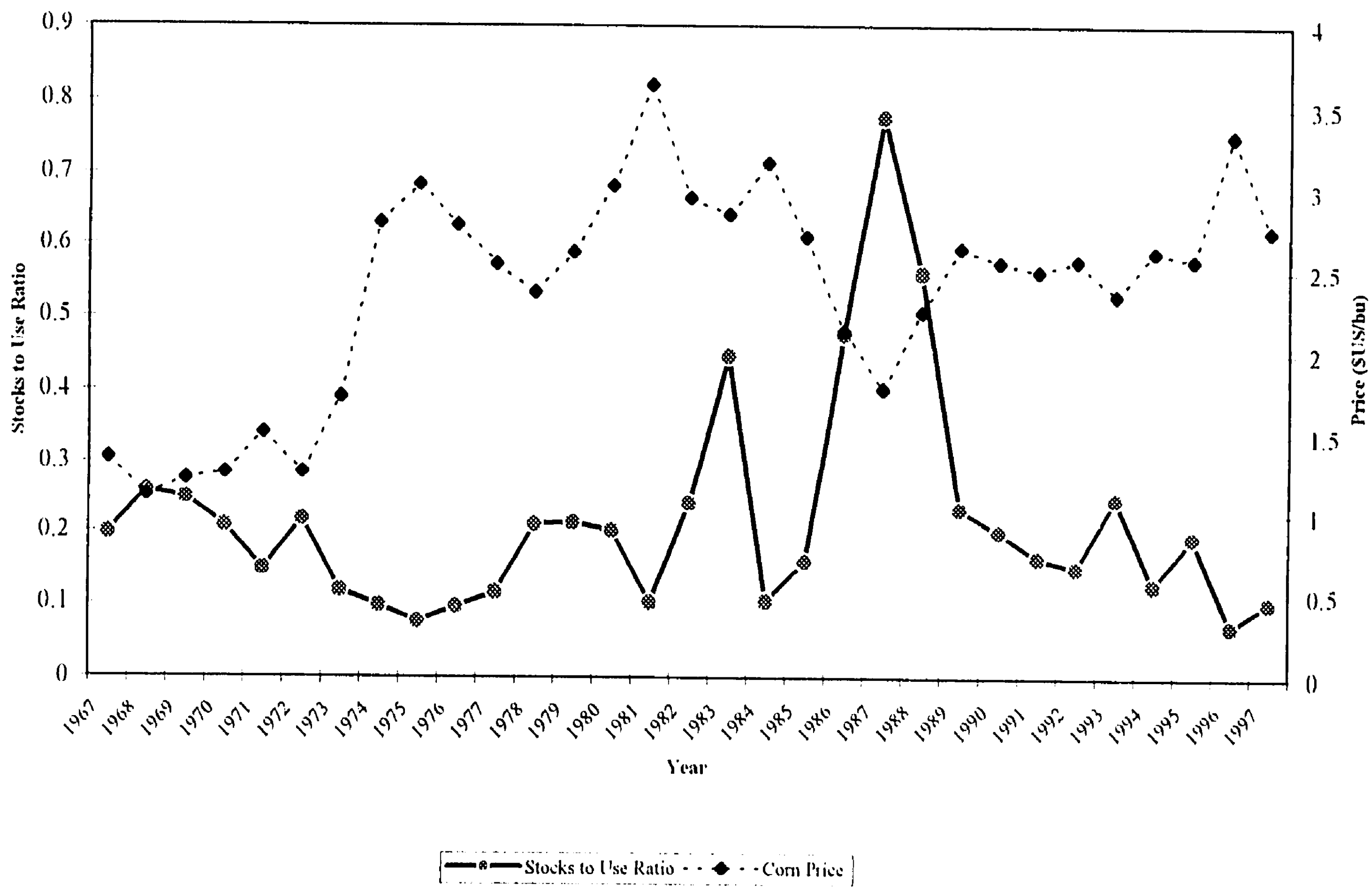


Figure A.3
Wheat Stocks to Use versus Price

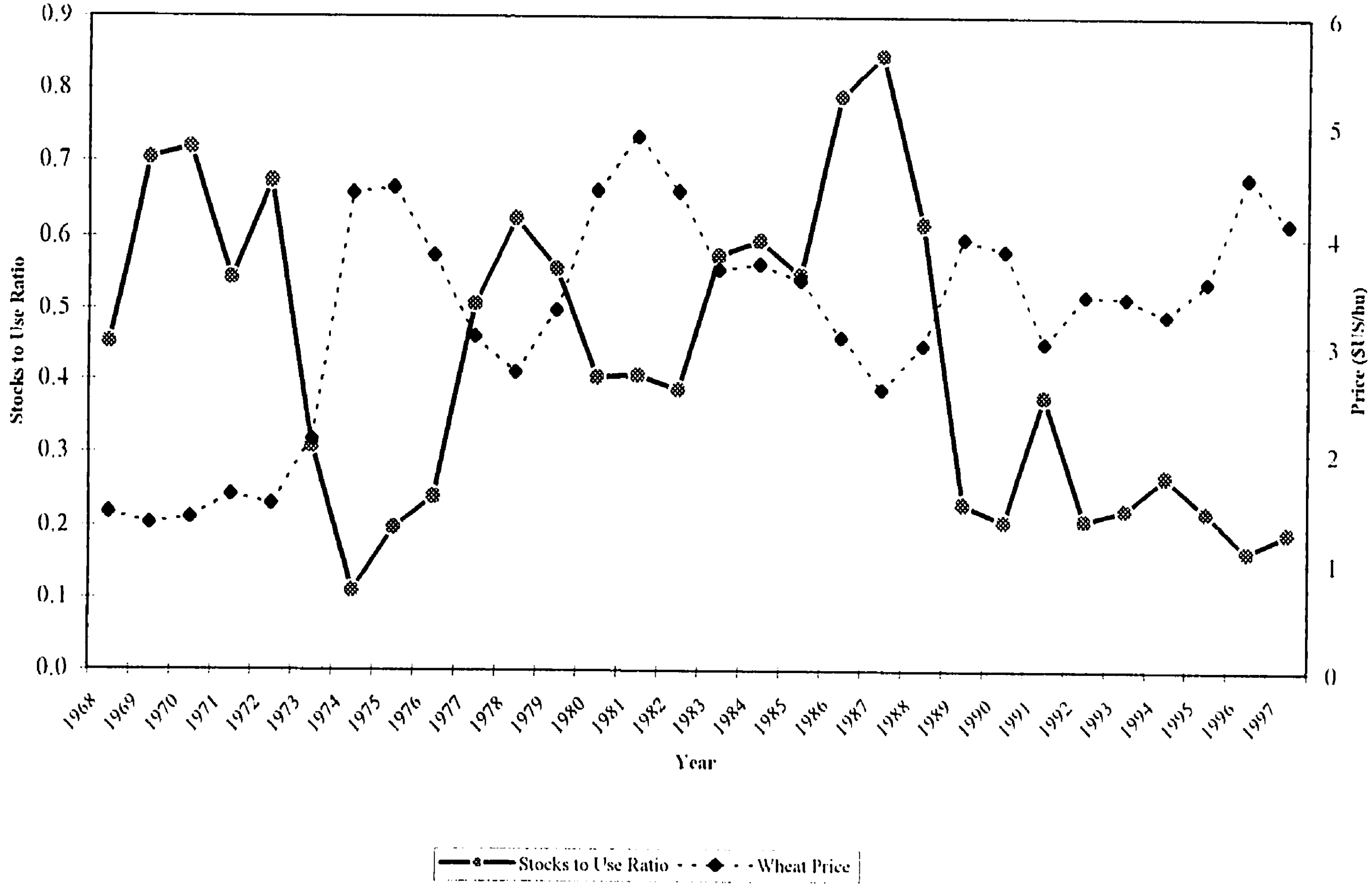
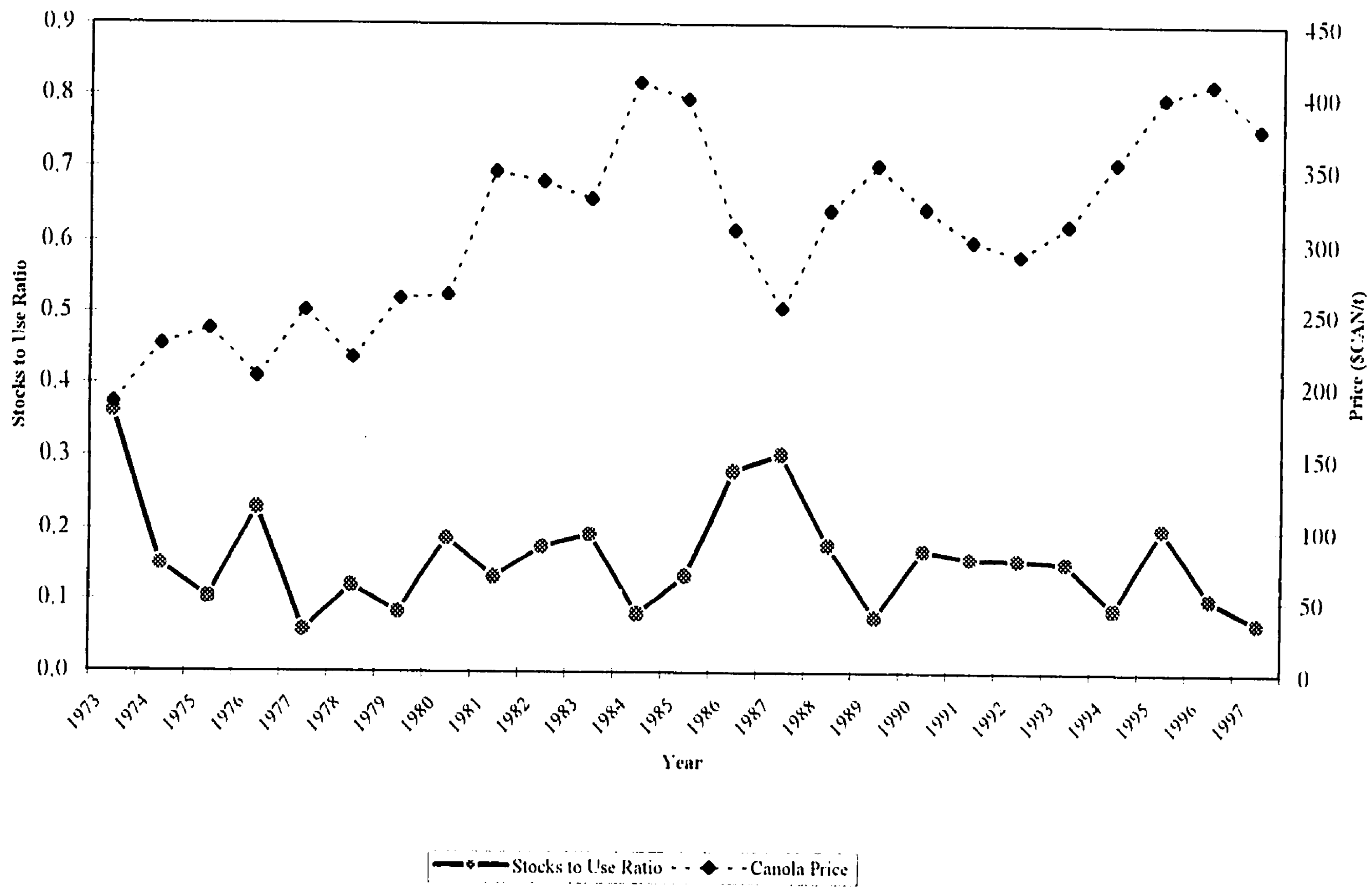


Figure A.4
Canola Stocks to Use versus Price



APPENDIX B

Selected Regression Results

Table B.1

Regression Results for Models Used in Study[a,b]

Dependent Variable: Price		Independent Variable			
Years	Commodity	Constant	Stocks/Use	R^2	F-Stat
1967-1997	Oats	2.51 (13.14)*	-2.87 (-5.92)*	0.55	35.01*
1967-1997	Corn	2.69 (13.15)*	-1.35 (-1.75)*	0.10	3.08**
1968-1997	Wheat	4.52 (12.75)*	-2.89 (-3.9)*	0.35	15.21*
1973-1997	Canola	361.40 (12.42)*	-346.51 (-2.08)*	0.16	4.31*

*Indicates statistical significance at the 5% level

**Indicates statistical significance at the 10% level

[a]T-ratio appears in parentheses

[b]Prices are in $US/bushel, except for canola which is in $CAN/tonne

Table B.2

Regression Results for Models Not Used in Study, with Oats Prices as the Dependent Variable, 1967-1997[a,b]

		Independent Variables				
Constant	Stocks/Use	Ending Stocks	Net Exports	Production	R^2	F-Stat
2.024 (20.44)*		-0.002546 (-7.04)*			0.63	49.5*
2.21 (16.62)*		0.00337 (1.96)*	-0.0311 (-6.92)*		0.68	29.1*
2.49 (11.00)*	-0.00039 (-0.22)		-2.8185 (-5.16)*		0.55	17.0*
2.807 (10.71)*		-0.0017 (-2.58)*	0.0078 (3.36)*	-0.00147 (-1.95)*	0.74	25.5*

*Indicates statistical significance at the 5% level

[a]T-ratio appears in parentheses

[b]Prices are in $US/bushel