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by
Daniel Sanders, Corinne Alexander,
and Matthew Roberts

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Daniel J. Sanders,

Corinne Alexander,

and

Matthew C. Roberts*

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* Daniel Sanders (sander16@purdue.edu) and Corinne Alexander are graduate student and associate professor, respectfully, in the Department of Agricultural Economics at Purdue University. Matthew C. Roberts is an associate professor in the Department of Agricultural, Environmental and Development Economics at The Ohio State University.

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The price volatility observed in futures markets, beginning in 2006 and continuing through to the present, has posed challenges to commercial traders attempting to use these markets to hedge their price risk. Additionally, speculative activity in these markets is seemingly on the rise, with large index funds drawing the ire of many as a possible driver of price volatility and high price levels. Taken in concert, these issues have led some to question the ability of the markets to continue to provide for adequate hedging functionality. In this paper, we attempt to determine if the rate at which commercial traders hedge in the markets has changed by testing for structural change in the relationship between open interest and physical grain stocks. A significant structural break is found in the wheat market in late 2004. A more detailed examination of the break is done by incorporating smooth transition and threshold models, with the positive relationship between open interest and stocks shown to decline to statistically zero around the structural break. Given the development of non-convergence in the wheat market at this time, it suggests that wheat hedgers might be using alternative hedging outlets. Overall, the estimated models show generally poor fits, indicating that there might be other factors than are present in the structural model influencing hedgers' positions in futures markets.

Keywords: futures markets, open interest, grain stocks, hedging, smooth transition model, threshold model

Introduction

It has long been held that one of the principal functions of futures markets is to provide a means of hedging for economic agents. This idea has been clearly defended in the classical papers of Working (1953, 1960, 1962), and has been a core rationale in many of the decisions made regarding the markets' design and maintenance. The ability to effectively and efficiently hedge price risk has been an important economic tool for many industries, although this emphasis on hedging does not imply that speculative activity is not important to the markets. To the contrary, all else equal hedgers will prefer the market with the greater speculative action, as it provides liquidity that reduces the transactions costs of trading in these markets. However, no market can continue to function without the active participation of traders. The great example of this is the near collapse of the Kansas City Board of Trade (KCBOT) wheat contract in 1953, as hedgers left the market due to the inadequacy of the contract's specifications to provide appropriate price protection (Working, 1960).

The important role of hedging to the health of agricultural commodities futures markets is worth remembering in the face of rising market challenges, namely, price volatility and increased speculation. Beginning in 2006 and continuing to the present, agricultural commodities markets began to demonstrate notable volatility, with prices racing to record or near record highs, collapsing, and returning to test the recent records. In the face of these price movements, the concurrent expansion of speculative activity has been critically examined as one possible driver of prices. Specifically, the large positions taken by long-only index funds have come under scrutiny for perceived inflationary pressure on prices. The principal concern is that this speculative activity is sufficiently large to drive the market of its own accord, weakening the role of fundamental market information in price formation. However, as detailed by Sanders, Irwin, and Merrin (2010), speculation in the agricultural commodity markets has been within the historical ranges for these commodities. Most examinations on the impact of speculation have used prices as the focus of analysis; some examples include: Sanders, Boris & Manfredo, 2004; Bryant, Bessler & Haigh, 2006; Abbott, Hurt & Tyner, 2008; Irwin, Sanders & Merrin, 2009; Gilbert, 2010. However, as seen in these studies, prices can reflect a number of differing influences and provide a challenge for determining the specific influence of one particular factor on the market.

Given the challenges that are present in the market and the extraneous information in prices, perhaps the most useful measure of the ongoing effectiveness of the futures market for hedging is in the actions of commercial traders themselves. If the futures market is no longer providing sufficient price hedging protection for commercial traders, it might be believed that the rational trader would move his or her hedging to alternative activity. It should be noted that as a practical matter, there are relatively few options for price hedging that are as efficient as using the futures market. However, marketing agreements such as forward contracts do provide alternatives, and the increasingly integrated agricultural production system can offer more opportunities for these types of arrangements. We can also look back to Johnson's classic mean-variance hedge ratio to understand why hedgers might lessen their use of the futures market; the basis for most modern hedge ratios (Chen, Lee, & Shrestha, 2003), it can provide some additional insight into hedgers' actions. The mean-variance ratio is derived to be:

$$MV\ hedge\ ratio = \rho \frac{\sigma_s}{\sigma_f}$$

Where ρ is the correlation between the futures and spot markets, σ_s is the standard deviation of the spot market, and σ_f is the standard deviation of the futures market (Johnson, 1960). If the futures market has increased volatility, increasing σ_f, or if the correlation between the two markets decreases, as might be the case if speculation is undermining the market fundamentals, then the hedge ratio will decline. Although this project is not directed at hedge ratios specifically, this simple example clearly demonstrates that if market conditions change and provide less adequate price protection, then hedgers' use of these markets should decline.

The use of the futures market for hedging by commercial traders should be described by the relationship between commercial open interest and physical stocks of the commodity. The positive correlation between futures open interest and physical stocks has been examined in the past, notably by Irwin (1935), Working (1953, 1960), and Peck (1980). However, to our knowledge no recent examination of this correlation has been undertaken. If this connection is found to be weakening over time, it might indicate that hedgers are finding alternative outlets for their hedging needs.

In the remainder of this paper, we detail the propositions that should provide a logical basis for hedgers' use of the futures markets and a structural model that tests this relationship. The data available to fit this model is described, with its advantages and disadvantages relative to the structural model described. The model is estimated for four commodities using different data sources, and is tested for structural change in the relationship between open interest and physical stocks. Finally, a structural break in the wheat market is subjected to a more detailed examination, and the findings of the paper and some implications are discussed.

Model Specification

The specification of this model is based on two propositions:

1. *Hedgers participate in the futures market only to hedge risk.*

2. *Whenever possible, hedgers move price risk off their books upon receipt, either into forward contracts or into the futures market.*

Of these two points, the first is relatively innocuous. Participants trading on organized exchanges are required to file their classification with the U.S. Commodity Futures Trading Commission (CFTC). As the classification determines position limits and margin requirements, proper identification is important and carries notable penalties for those that are misleading in their classification. In essence, the Proposition 1 assumes that hedgers are appropriately participating in the system, and that their positions are wholly for hedging purposes.

The second point is more subtle than the first. Here, hedgers need only be holding the price risk for the commodity, not the commodity itself; indeed, the physical goods may not even have been produced yet. One common example might be found in a farmer forward contracting in February with his local elevator for the December delivery of a portion of his expected crop. The elevator would, in turn, move this price risk into the futures market or into a forward contract with a processor for delivery in January. In either case, the price risk does not stay with the hedger, but has instead been accepted and transferred into the larger market even though the bushels do not yet exist. It should be noted that the producer is also classically a hedger as well, and in this case behaves as hedger might by entering forward contract. However, practical observers of the market would observe that many farmers do not actively forward market the majority of their grain, and that a considerable portion of price risk is simply held by the farmer. This observation is a legitimate concern, and Proposition 2 might be more accurately characterized as pertaining to actively participating hedgers.

Based on these two propositions, it is then logical that the only reason that a hedger would change his position in the futures market is that his quantity of price risk has changed. If the price risk is associated with the grain that he is buying or selling, then a simple structural model is dictated:

$$\Delta(open\ interest)_t = \beta_0 + \beta_1 \Delta(stocks)_t + \varepsilon_t$$

Here, $\Delta(open\ interest)_t$ is the change in commercial open interest in a commodity futures market, and $\Delta(stocks)_t$ is the change in the stocks of that commodity for which hedgers hold the price risk. We can make some firm hypotheses about the coefficients; β_0 is hypothesized to be zero, such that there are not systematic influences other than changes in stocks directing changes in commercial open interest. β_1 is hypothesized to be the percentage of stocks normally hedged in the futures market. In a world in which production is known, forward contracts are not available, and futures market participation has no transactions costs, then it is likely that β_1 would approach one given risk averse market participants. With the addition of forward contracts, β_1 would reflect the split between forward and futures contracts. Given market frictions and the relatively low levels of forward marketing by farmers (Wong, Makus & Chen, 2004), β_1 is expected to be much smaller, while still bounded by zero and one.

Data

The open interest data for the structural equation comes from the weekly Commitment of Traders (COT) report issued by the CFTC. This report breaks out open interest in long, short and spread (for non-commercials only) positions, as well as total, "old," and "other" open interest. Old open interest contains open interest in the current old crop futures only, while other open interest is for all other traded contracts.[1] COT reports are available for futures market positions only, as well as for futures and options positions combined, with options positions turned into equivalent synthetic futures positions through their delta values.

For this work, the data was pared down to provide the sharpest perspective possible, under the idea that if the hypothesized relationships exist, they should be most evident in the most tightly defined set. Commercial open interest, which is composed only of commercial traders, i.e., hedgers, is the set of interest. The clear majority of hedgers hold short positions, such that hedgers as a whole are generally labeled as net short; accordingly, this research uses only the open interest in short positions. Both 'all' and 'old' open interest are used, with all open interest reflecting both storage and expected production hedges, while 'old' open interest might be expected to better align with the known quantities of grain on hand in storage. Finally, the futures-only set was used. Although some hedging may be done with options, these derivatives can be used in combination with other hedging instruments, and these coexisting factors are not expected to have the same impact on the futures-only data (CFTC 2011).

The stocks data posed a greater challenge, as the stocks needed are those for which active hedgers hold the price risk, which could include stocks currently in storage, expected production from the current crop, or even expected production from future crops. The expectations of future stocks are difficult to measure, with perhaps the best regular estimates being the estimated production numbers provided in the World Agricultural Supply and Demand Estimates (WASDE) reports issued monthly by the World Agricultural Outlook Board. These reports provide a balance sheet for commodities, including beginning supply, estimated production, trade, use and consumption, and expected ending stocks (USDA, 2011a). Quantities of actual stocks on hand are reported quarterly by the National Agricultural Statistics Service (NASS), which details total stocks as well as breaking down on- and off-farm stocks (USDA, 2011b). These reports lack the anticipated bushels, but provide an excellent estimate of available grain. Both of these data sources were separately used to estimate the model.

[1] For the commodities studied here, the first and last contract months in the crop year are: corn, December-September; soybeans, September-August; wheat, July-May; oats, July-May.

Four different commodities were examined within this project, namely, corn, soybeans, wheat and oats, with three different measures of these grain stocks used from the two reports. From the WASDE reports, the current estimate of total supply was used. This estimate would include both expected bushels on hand in storage as well as anticipated production. The total supply estimate also includes imports, but for these agricultural commodities imports are an insignificant portion of total supply. The off-farm and total stocks were used from the NASS reports; the on-farm stocks measure was not used due to the regularity with which these stocks go un-hedged. Additionally, all the measures of commodity stocks were adjusted to units of 5,000 bushels to be equal in size to a futures contract. The data was first differenced to align with the changes in stocks postulated in the model formulation, resulting in 179 usable observations for the WASDE data and 59 observations for the NASS data.

The open interest data is reported in weekly format; for each stocks data source, the COT report date closest to the stocks report data was used. As the wheat stocks were reported in aggregate without regard to the class of wheat, the open interest for wheat was aggregated across the three main wheat markets: Minneapolis Grain Exchange, Kansas City Board of Trade, and Chicago Board of Trade. The futures open interest for the other commodities are drawn only from the Chicago Board of Trade. Here again, the data was first differenced to align with the structural model. The use of first-differencing as indicated by the model conveniently allows this project to avoid stationarity issues usually associated with time-series data. All the first differenced data were stationary, as measured by Augmented-Dickey Fuller tests (Table 1).

It is evident that neither data source perfectly fits the data requirements, nor is there an available data source known to the authors that does. The choice is between a structural econometric model for which no well-fitting data source exists, or a non-structural model such as vector autoregression which is more amenable to the available data but lacks the economic intuition. For this application, we have chosen to use the structural model with an awareness of the problems that the data poses for us.

Analysis and Results

For each of the four commodities, five variations of the structural model were estimated using the econometric packages in *SAS 9.2* and *R 2.11.1*. Changes in all short commercial open interest and changes in old short commercial open interest were separately regressed against changes in the NASS estimates of off-farm stocks and against changes in total stocks of grain, and changes in all short commercial open interest were regressed against changes in the WASDE estimates of total supply of grain. Given the presence of anticipated production bushels in the supply estimates, the old measure of open interest was not put into a model with supply. These results are reported in Table 2.

The results for corn show a pattern that recurs across the commodities, namely, relative poor fits for the structural model. For all five variations of the structural estimation, the model explains less than ten percent of all variation in the changes in open interest. This deficiency in fit is especially notable in the estimates using old open interest as the dependent variable, which have

R^2 values well under 0.01. Two points do stand out among the corn results, however. One, the intercept term for all the estimates is statistically zero, which is in line with the hypothesis proposed by the structural model. Secondly, the model estimated using the WASDE supply estimate shows strong significance on the stocks variable, but the estimate itself is negative, such that increases in the estimated supply of corn are strongly correlated with decreasing commercial positions in the futures market. Taken in isolation, one might attribute this change to speculative actions, as an increase in the supply of corn could have bearish price implications. However, this negative sign is consistent across all four commodities, suggesting that there is some systematic factor that is influencing the sign, although no logical explanations consistent with hedging behavior have been determined.

The soybean estimates closely mirror those of corn, with models using old open interest underperforming models that use all open interest, and all models demonstrating relatively low explanatory power. Again, the intercept term is statistically zero, while the strongest relationship between open interest and stocks found in the regression of all open interest on off-farm stocks of soybeans. The model estimated using the WASDE supply estimates showed negative coefficient estimates on the stocks variable as well. Overall, the soybean models did not provide much insight into the relationship between stocks and open interest.

The consistent negative signs on the models that employed the WASDE estimates are also reflected in all the models estimated for the oats market using the NASS stocks estimates. Again, there are no immediately recognizable reasons for the unlikely direction on these coefficients. However, as we look past the signs on the estimates, we can see that the structural model is perhaps best represented in this market. The models using NASS data demonstrate the most explanatory power, and have consistent significance for the stocks variable and insignificance for the intercept. Furthermore, the nominal size of the coefficients is more consistent with what might be expected for changes in open interest given changes in their underlying stocks. It is worth noting at this point that the oats market is considerably smaller than the other three markets, and has not been noted as having the same speculative issues.

The most interesting results from the structural model estimations are found in the wheat market. These models show the same fit issues that plague the other three commodities, although at least within the NASS-based models, all the coefficient signs are positive and all the intercepts are statistically zero. What distinguishes this commodity as meriting further examination is the presence of a possible structural change in the relationship between open interest and stocks.

The examination of structural change was done on these same models using standard Chow tests for structural breaks. The examination was initially conducted in the NASS models by testing for breaks at every fifth observation, starting at the tenth observation and continuing through to the fiftieth observation. For the model employing WASDE data, breaks were tested for every twenty-fourth observation, starting at observation twenty-four and continuing through to the 168^{th} observation. If a significant or near-significant break was found, then the every observation around the initial point was examined, with the strongest significance taken as the stated structural break. The results of the Chow test are presented in Table 2.

At a significance level of at least α = 0.10, all the commodities except soybeans showed a structural break in at least one estimated model. However, only wheat showed a consistent structural break across multiple variations of the structural model, with the break narrowed down to its most significant point in the all open interest and total stocks model between the thirty-eighth and thirty-ninth observations. Applying these observation numbers to the quarterly nature of the data, we observe that the structural break in the wheat market is between the September and December quarterly observations in 2004. Using the monthly data in the WASDE report, the break is refined to be between October and November of 2004. This time period is especially notable given that it immediately precedes the beginning of the non-convergence in basis that has caused so many problems in the wheat market in recent years.

To further examine this structural break in wheat, we turn to models that explicitly incorporate structural change, specifically to smooth transition and threshold models. Smooth transition models incorporate a transition function, generally logarithmic or exponential, that smoothly transitions between the values of zero and one (Lin and Teräsvirta, 1994). The estimation of the function requires estimating variables that measure both the speed of transition and its central point. As the speed of transition gets very small, the model transitions very slowly and approaches that of a model without structural change; in turn, as the speed of transition get very large, the smooth transition model approximates a threshold model.

To employ a smooth transition model, the non-linear model is first tested for non-linearity and the appropriate transition function using a Taylor series expansion test which posits the non-linear variables to be zero as the null hypothesis. For the wheat market, the test shows that the model was non-linear, and that the logarithmic, or LSTAR, model was the best fit. The LSTAR model was estimated as:

$$y_t = (\beta_0 + \beta_1 x_t) * \left(1 - G(t^*, \sigma_{t^*}; \gamma, c)\right) + (\alpha_0 + \alpha_a x_t) * G(t^*, \sigma_{t^*}; \gamma, c) + \varepsilon_t$$

Where:

$$G(t^*, \sigma_{t^*}; \gamma, c) = \{1 + exp(-\gamma(t^* - c)/\sigma_{t^*})\}^{-1}$$

The variables y_t and x_t are the changes in open interest and changes in total stocks, respectfully. The parameters t^* and σ_{t^*} are a time trend normalized to lie between zero and one and its standard deviation, while c is a centrality parameter that denotes the midpoint of the transition. Finally, γ is the speed of transition parameter; as γ approaches zero, the model approximates one without structural change, while as γ gets very large it approaches the threshold model. For comparison, a threshold model is also estimated:

$$y_t = (\beta_0 + \beta_1 x_t) * (1 - d) + (\alpha_0 + \alpha_a x_t) * d + \varepsilon_t$$

Where d = 1 after September 2004 and zero otherwise. Here, the structural change is modeled as being nearly instantaneous, with the switching of regimes completed entirely within one period. The results of these two models are presented in Table 3.

The incorporation of structural change in the model shows immediate improvement over the original linear model. Whereas the stocks variable showed no significance in the original specification, we now see that stocks are statistically significant before the structural change begins, and insignificant once it is complete. These results are same for both structural change models, both of which provide a better fit than the original linear model. Of the two structural change models, the threshold model provides the better fit, indicating that the structural change is relatively abrupt in nature. The fairly high value of the speed of transition parameter ($\gamma = 12.43$) in the smooth transition model reflects this rapid switching from one regime to the other. Taken in the combination, the structural change models indicate there was a positive, albeit small, relationship between open interest in wheat and physical stocks of the commodity that abruptly ended in late 2004.

Conclusions and Extensions

The continued price volatility in futures markets has been an ongoing concern for market participants of all types. Compounding the concern over price volatility has been the apparent rise in speculation in these markets, with large index funds coming under scrutiny for their significant long-only holdings. In the face of these challenges, the viability of the market for hedgers is being quietly questioned in some corners. This project proposed that the suitability of the market for commercial traders could be gauged by hedgers' participation in these markets; if these market participants no longer see value in the market, their engagement might be slipping with time. To this end, we constructed a structural model that proposed to test the ongoing relationship between commercial open interest and physical stocks of commodities.

Overall, the models demonstrated a consistent lack of fit, with the independent variables providing relatively little explanatory power. Two possible issues that could be the cause of the relatively poor fits are data concerns and factors from outside the current structural model. The data issue is one that has been noted before, that is, it is very difficult to measure the amount of stocks for which hedgers hold the price risk. These stocks would include grain in storage, grain currently in production, and grain anticipated to be produced in the future. One direction that could be explored would be to narrowly focus on old open interest and the stocks in storage while incorporating a measure of the percentage of the crop that has been marketed. Although the bushels may have entered the market as forward contracts during production, bringing in some metric for marketing could better capture the transition of price risk to active hedgers.

A missing element from the structural model is the more conceptually interesting issue. If hedgers are not acting in accordance with the motivations we would expect for these market participants, then their rationale for hedging could be more in line with those of speculators. The possibility of speculative motivations is not unlikely, as no grain can enter the market without the original producer putting it in, and if these producers are willing to manage some of their grain in a speculative fashion, then the relationship between stocks and open interest might need to also incorporate some measure of the expectation of future prices. Indeed, if traditionally active hedgers are acting simply as a conduit for price risk to move into the futures markets and our second proposition above holds, then the relatively low explanatory power of changes in stocks might best reflect farmers' willingness (or lack of thereof) to market their grain in a consistent fashion. If this is case, variables such as farmers' expectations of future prices or farm-level cash flows might better explain the changes in hedgers' open interest.

Although there are some specific notes in the literature which suggest that hedgers' motivations are sufficiently complex across the whole of commercial traders to make disentangling them a serious challenge (for one example, see Williams, 2001), understanding hedgers' actions could provide insight into the movement of risk through the production chain. Acknowledging the estimation issues, there are still clear indications here of a significant shift in the wheat markets which underscore the importance of mapping the transference of risk through marketing channels. If hedgers have actually begun to move away from using the wheat market to hedge their price risk, be that motivated by non-convergence issues in wheat basis or by other factors, that migration could have serious implications for the continued functioning of the futures market. Without a robust commercial presence, the connection between the futures and spot market could begin to slip, further discouraging hedging and harkening back to the troubles of the KCBOT in 1953. Accordingly, as we see little support for physical stocks making a significant contribution to explaining hedgers' participation in futures markets, as well as evidence in the wheat market that this relationship could be in decline, the need to understand hedgers' actions and the flow of price risk from producers through to futures markets is becoming ever more important.

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Table 1. Augmented Dickey-Fuller tests for stationarity in first differences of stocks and open interest variables.

Panel 1.A: ADF test with two lags of changes in NASS off-farm corn stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	113.086	0.0001	-43.65	<0.0001		
Constant	112.977	0.0001	-44.15	0.0001	974.79	0.0010
Constant and trend	112.973	0.0001	-43.76	<0.0001	958.92	0.0010

Panel 1.B: ADF test with two lags of changes in NASS off-farm soybean stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	112.726	0.0001	-53.16	<0.0001		
Constant	112.721	0.0001	-52.67	0.0001	1387.37	0.0010
Constant and trend	112.733	0.0001	-52.12	<0.0001	1362.76	0.0010

Panel 1.C: ADF test with two lags of changes in NASS off-farm wheat stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	117.536	0.0001	-30.82	<0.0001		
Constant	117.481	0.0001	-30.70	0.0001	471.19	0.0010
Constant and trend	117.432	0.0001	-30.40	<0.0001	462.37	0.0010

Panel 1.D: ADF test with two lags of changes in NASS off-farm oats stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-1536.890	0.0001	-7.28	<0.0001		
Constant	-1538.270	0.0001	-7.22	0.0001	26.06	0.0010
Constant and trend	857.855	0.0001	-7.85	<0.0001	30.92	0.0010

Panel 1.E: ADF test with two lags of changes in NASS total corn stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	110.885	0.0001	-56.20	<0.0001		
Constant	110.852	0.0001	-56.60	0.0001	1602.04	0.0010
Constant and trend	110.853	0.0001	-56.32	<0.0001	1589.99	0.0010

Panel 1.F: ADF test with two lags of changes in NASS total soybean stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	112.381	0.0001	-53.09	<0.0001		
Constant	112.381	0.0001	-52.59	0.0001	1382.77	0.0010
Constant and trend	112.365	0.0001	-52.03	<0.0001	1357.91	0.0010

Panel 1.G: ADF test with two lags of changes in NASS total wheat stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	114.980	0.0001	-38.62	<0.0001		
Constant	114.962	0.0001	-38.40	0.0001	737.15	0.0010
Constant and trend	114.966	0.0001	-38.02	<0.0001	722.97	0.0010

Panel 1.H: ADF test with two lags of changes in NASS total oats stocks

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	128.769	0.0001	-22.18	<0.0001		
Constant	128.251	0.0001	-22.32	0.0001	249.11	0.0010
Constant and trend	126.884	0.0001	-23.55	<0.0001	277.26	0.0010

Table 1. Augmented Dickey-Fuller tests for stationarity in first differences of stocks and open interest variables, cont'd.

Panel 1.I: ADF test with two lags of changes in WASDE corn supply

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-250.779	0.0001	-8.54	<0.0001		
Constant	-261.495	0.0001	-8.62	<0.0001	37.12	0.0010
Constant and trend	-271.144	0.0001	-8.66	<0.0001	37.55	0.0010

Panel 1.J: ADF test with two lags of changes in WASDE soybean supply

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-253.897	0.0001	-8.57	<0.0001		
Constant	-258.642	0.0001	-8.60	<0.0001	36.99	0.0010
Constant and trend	-259.719	0.0001	-8.59	<0.0001	36.92	0.0010

Panel 1.K: ADF test with two lags of changes in WASDE wheat supply

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-155.645	0.0001	-7.26	<0.0001		
Constant	-156.062	0.0001	-7.25	<0.0001	26.30	0.0010
Constant and trend	-159.469	0.0001	-7.30	<0.0001	26.68	0.0010

Panel 1.L: ADF test with two lags of changes in WASDE oats supply

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-184.815	0.0001	-7.68	<0.0001		
Constant	-203.242	0.0001	-7.93	<0.0001	31.45	0.0010
Constant and trend	-220.721	0.0001	-8.09	<0.0001	32.75	0.0010

Panel 1.M: ADF test with two lags of changes in all COT corn open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-507.128	0.0001	-13.81	<0.0001		
Constant	-507.140	0.0001	-13.80	<0.0001	95.28	0.0010
Constant and trend	-507.711	0.0001	-13.80	<0.0001	95.28	0.0010

Panel 1.N: ADF test with two lags of changes in all COT soybean open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-629.977	0.0001	-14.90	<0.0001		
Constant	-629.973	0.0001	-14.89	<0.0001	110.90	0.0010
Constant and trend	-630.498	0.0001	-14.88	<0.0001	110.79	0.0010

Panel 1.O: ADF test with two lags of changes in all COT wheat open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-614.093	0.0001	-14.90	<0.0001		
Constant	-614.084	0.0001	-14.89	<0.0001	110.90	0.0010
Constant and trend	-614.727	0.0001	-14.88	<0.0001	110.79	0.0010

Panel 1.P: ADF test with two lags of changes in all COT oats open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-770.907	0.0001	-16.03	<0.0001		
Constant	-773.249	0.0001	-16.04	<0.0001	128.65	0.0010
Constant and trend	-776.353	0.0001	-16.05	<0.0001	128.83	0.0010

Table 1. Augmented Dickey-Fuller tests for stationarity in first differences of stocks and open interest variables, cont'd.

Panel 1.Q: ADF test with two lags of changes in old COT corn open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-733.228	0.0001	-15.76	<0.0001		
Constant	-733.245	0.0001	-15.75	<0.0001	124.09	0.0010
Constant and trend	-733.794	0.0001	-15.75	<0.0001	124.00	0.0010

Panel 1.R: ADF test with two lags of changes in old COT corn open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-666.351	0.0001	-15.23	<0.0001		
Constant	-666.352	0.0001	-15.22	<0.0001	115.86	0.0010
Constant and trend	-666.674	0.0001	-15.21	<0.0001	155.74	0.0010

Panel 1.S: ADF test with two lags of changes in old COT corn open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-857.464	0.0001	-16.66	<0.0001		
Constant	-857.544	0.0001	-16.65	<0.0001	138.56	0.0010
Constant and trend	-857.642	0.0001	-16.64	<0.0001	138.39	0.0010

Panel 1.T: ADF test with two lags of changes in old COT corn open interest in futures

Type	ρ	ρ: p-value	τ	τ: p-value	F	F: p-value
No constant	-1067.470	0.0001	-17.77	<0.0001		
Constant	-1068.310	0.0001	-17.76	<0.0001	157.76	0.0010
Constant and trend	-1069.490	0.0001	-17.76	<0.0001	157.65	0.0010

Table 2. Estimates and Chow tests of the structural model between changes in changes in stocks of grain and changes in open interest.

Panel 2.A: Old corn open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	5669	12293	0.6464
Off-farm stocks	0.0207	0.0493	0.6758
Durbin-Watson	2.5414		
R-squared	0.0031		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.09	0.9127
Chow	15	0.11	0.8972
Chow	20	0.27	0.7610
Chow	25	0.59	0.5582
Chow	30	0.59	0.5594
Chow	35	0.21	0.8107
Chow	40	0.29	0.7504
Chow	45	0.05	0.9558
Chow	50	1.09	0.3431

Panel 2.B: All corn open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	6607	13559	0.6279
Off-farm stocks	0.0935	0.0543	0.0906
Durbin-Watson	1.9033		
R-squared	0.0494		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.08	0.9206
Chow	15	0.08	0.9266
Chow	20	0.05	0.9481
Chow	25	0.06	0.9387
Chow	30	0.05	0.9507
Chow	35	0.16	0.8526
Chow	40	0.17	0.8454
Chow	45	0.51	0.6055
Chow	50	0.51	0.6017

Panel 2.C: Old corn open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	5662	12297	0.6469
Total stocks	0.0058	0.0148	0.6970
Durbin-Watson	2.5418		
R-squared	0.0027		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.08	0.9211
Chow	15	0.09	0.9140
Chow	20	0.22	0.7998
Chow	25	0.50	0.6080
Chow	30	0.51	0.6050
Chow	35	0.19	0.8303
Chow	40	0.26	0.7702
Chow	45	0.01	0.9862
Chow	50	0.77	0.4661

Panel 2.D: All corn open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	6662	13707	0.6288
Total stocks	0.0214	0.0165	0.2000
Durbin-Watson	1.9043		
R-squared	0.0287		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.11	0.8983
Chow	15	0.08	0.9219
Chow	20	0.07	0.9364
Chow	25	0.10	0.9077
Chow	30	0.08	0.9258
Chow	35	0.11	0.8938
Chow	40	0.11	0.8931
Chow	45	0.41	0.6660
Chow	50	0.49	0.6165

Table 2. Estimates and Chow tests of the structural model between changes in changes in stocks of grain and changes in open interest, cont'd.

Panel 2.E: Old soybeans open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	3826	4980	0.4455
Off-farm stocks	0.0732	0.0491	0.1419
Durbin-Watson	2.1999		
R-squared	0.0375		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.43	0.6500
Chow	15	0.10	0.9047
Chow	20	0.12	0.8842
Chow	25	0.14	0.8704
Chow	30	0.22	0.8038
Chow	35	0.11	0.8946
Chow	40	0.32	0.7244
Chow	45	0.45	0.6419
Chow	50	0.11	0.8950

Panel 2.F: All soybeans open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	4051	5075	0.4280
Off-farm stocks	0.1073	0.0501	0.0363
Durbin-Watson	1.9814		
R-squared	0.0747		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.65	0.5258
Chow	15	0.21	0.8138
Chow	20	0.30	0.7449
Chow	25	0.21	0.8119
Chow	30	0.33	0.7210
Chow	35	0.32	0.7303
Chow	40	0.44	0.6472
Chow	45	1.01	0.3701
Chow	50	0.69	0.5080

Panel 2.G: Old soybeans open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	3814	4986	0.4474
Total stocks	0.0317	0.0220	0.1546
Durbin-Watson	2.1863		
R-squared	0.0352		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.35	0.7040
Chow	15	0.08	0.9264
Chow	20	0.10	0.9030
Chow	25	0.14	0.8654
Chow	30	0.21	0.8083
Chow	35	0.09	0.9172
Chow	40	0.34	0.7147
Chow	45	0.42	0.6584
Chow	50	0.12	0.8858

Panel 2.H: All soybeans open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	4044	5114	0.4323
Total stocks	0.0431	0.0225	0.0607
Durbin-Watson	1.98		
R-squared	0.0604		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.53	0.5916
Chow	15	0.15	0.8614
Chow	20	0.20	0.8180
Chow	25	0.17	0.8475
Chow	30	0.23	0.7954
Chow	35	0.21	0.8149
Chow	40	0.42	0.6614
Chow	45	0.82	0.4453
Chow	50	0.55	0.5823

Table 2. Estimates and Chow tests of the structural model between changes in changes in stocks of grain and changes in open interest, cont'd.

Panel 2.I: Old wheat open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	2600	6492	0.6903
Off-farm stocks	0.0808	0.0672	0.2346
Durbin-Watson	2.4661		
R-squared	0.0247		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.11	0.8976
Chow	15	0.01	0.9878
Chow	20	0.16	0.8527
Chow	25	0.37	0.6935
Chow	30	0.61	0.5453
Chow	35	1.94	0.1533
Chow	40	2.36	0.1042
Chow	45	2.72	0.0747
Chow	50	1.03	0.3637

Panel 2.J: All wheat open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	4280	4817	0.378
Off-farm stocks	0.0698	0.0499	0.1676
Durbin-Watson	2.0291		
R-squared	0.0331		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.17	0.8413
Chow	15	0.01	0.9856
Chow	20	0.30	0.7406
Chow	25	0.55	0.5774
Chow	30	1.24	0.2968
Chow	35	3.62	0.0333
Chow	40	4.09	0.0220
Chow	45	3.34	0.0427
Chow	50	1.38	0.2597

Panel 2.K: Old wheat open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	2617	6477	0.6877
Total stocks	0.0518	0.0396	0.1963
Durbin-Watson	2.4716		
R-squared	0.0291		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.12	0.8882
Chow	15	0.01	0.9908
Chow	20	0.12	0.8877
Chow	25	0.31	0.7327
Chow	30	0.54	0.5853
Chow	35	1.81	0.1741
Chow	40	2.21	0.1193
Chow	45	2.56	0.0867
Chow	50	1.08	0.3480

Panel 2.L: All wheat open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	4325	4844	0.3757
Total stocks	0.0337	0.0296	0.2605
Durbin-Watson	2.0277		
R-squared	0.0222		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.17	0.8444
Chow	15	0.02	0.9791
Chow	20	0.36	0.6981
Chow	25	0.69	0.5052
Chow	30	1.49	0.2339
Chow	35	4.29	0.0185
Chow	40	4.87	0.0113
Chow	45	3.76	0.0294
Chow	50	1.82	0.1716

Table 2. Estimates and Chow tests of the structural model between changes in changes in stocks of grain and changes in open interest, cont'd.

Panel 2.M: Old oats open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	79.2803	421.9902	0.8516
Off-farm stocks	-0.7662	0.2088	0.0005
Durbin-Watson	2.6613		
R-squared	0.1911		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.77	0.4699
Chow	15	0.19	0.8258
Chow	20	0.07	0.9368
Chow	25	0.17	0.8429
Chow	30	0.19	0.8294
Chow	35	0.25	0.7790
Chow	40	0.20	0.8161
Chow	45	0.16	0.8485
Chow	50	0.02	0.9801

Panel 2.N: All oats open interest on off-farm stocks

Variable	Estimate	Standard Error	p-value
Intercept	25.5767	281.0929	0.9278
Off-farm stocks	-0.4175	0.1391	0.0040
Durbin-Watson	2.2666		
R-squared	0.1365		

Test	Break point (n)	F Value	Pr > F
Chow	10	1.58	0.2150
Chow	15	0.38	0.6870
Chow	20	0.07	0.9286
Chow	25	0.06	0.9398
Chow	30	0.46	0.6362
Chow	35	1.65	0.2010
Chow	40	0.79	0.4581
Chow	45	0.20	0.8157
Chow	50	0.05	0.9516

Panel 2.O: Old oats open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	65.8971	438.8393	0.8812
Total stocks	-0.1618	0.0566	0.0059
Durbin-Watson	2.3989		
R-squared	0.1255		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.35	0.7083
Chow	15	0.16	0.8524
Chow	20	0.01	0.9915
Chow	25	0.13	0.8771
Chow	30	0.14	0.8697
Chow	35	1.40	0.2561
Chow	40	0.68	0.5117
Chow	45	0.97	0.3871
Chow	50	0.81	0.4482

Panel 2.P: All oats open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	12.0243	268.1767	0.9644
Total stocks	-0.1363	0.0346	0.0002
Durbin-Watson	2.3163		
R-squared	0.2142		

Test	Break point (n)	F Value	Pr > F
Chow	10	0.81	0.4491
Chow	15	0.07	0.9285
Chow	20	0.09	0.9143
Chow	25	0.10	0.9018
Chow	30	0.70	0.5025
Chow	35	4.53	0.0150
Chow	40	2.13	0.1281
Chow	45	1.96	0.1501
Chow	50	1.86	0.1655

Table 2. Estimates and Chow tests of the structural model between changes in changes in stocks of grain and changes in open interest, cont'd.

Panel 2.Q: All corn open interest on corn supply

Variable	Estimate	Standard Error	p-value
Intercept	3356	3397	0.3245
Supply	-0.2343	0.0688	0.0008
Durbin-Watson	1.7389		
R-squared	0.0615		

Test	Break point (n)	F Value	Pr > F
Chow	24	0.51	0.6036
Chow	48	0.33	0.7206
Chow	72	0.07	0.9291
Chow	96	0.36	0.6996
Chow	120	0.47	0.6278
Chow	144	0.85	0.4311
Chow	168	2.72	0.0688

Panel 2.R: All soybean open interest on soybean supply

Variable	Estimate	Standard Error	p-value
Intercept	1489	1657	0.3702
Supply	-0.1759	0.0989	0.0771
Durbin-Watson	1.9908		
R-squared	0.0176		

Test	Break point (n)	F Value	Pr > F
Chow	24	0.02	0.9795
Chow	48	0.16	0.8532
Chow	72	0.08	0.9197
Chow	96	0.04	0.9599
Chow	120	0.36	0.6968
Chow	144	0.01	0.9948
Chow	168	1.44	0.24

Panel 2.S: All wheat open interest on wheat supply

Variable	Estimate	Standard Error	p-value
Intercept	1241	1588	0.4357
Supply	-0.0247	0.1249	0.8434
Durbin-Watson	2.2191		
R-squared	0.0002		

Test	Break point (n)	F Value	Pr > F
Chow	24	0.25	0.778
Chow	48	0.1	0.901
Chow	72	0.02	0.9789
Chow	96	0.45	0.6406
Chow	120	5.32	0.0057
Chow	144	2.8	0.0638
Chow	168	2.57	0.0794

Panel 2.T: All oats open interest on oats supply

Variable	Estimate	Standard Error	p-value
Intercept	-10.9372	98.5783	0.9118
Supply	-0.0946	0.0602	0.1180
Durbin-Watson	1.9796		
R-squared	0.0138		

Test	Break point (n)	F Value	Pr > F
Chow	24	0.43	0.6496
Chow	48	0.27	0.7625
Chow	72	0.36	0.6986
Chow	96	0.38	0.686
Chow	120	0.36	0.6947
Chow	144	0.01	0.9894
Chow	168	0.36	0.698

Table 3. Estimates of smooth transition and threshold models for changes in all open interest in wheat regressed on changes in total stocks of wheat. The original linear model is provided for comparison.

Panel 3.A: All wheat open interest on total stocks

Variable	Estimate	Standard Error	p-value
Intercept	4325	4844	0.376
Total stocks	0.03369	0.02964	0.260

AIC: 1413.255

Panel 3.B: Smooth transition model of all wheat open interest on total stocks in the estimated form with y_t and x_t representing changes in total open interest and changes in total stocks, respectfully:

$$y_t = (b_0 + b_1 x_t) * \left(1 - G(t^*, \sigma_{t^*}; \hat{\gamma}, \hat{c})\right) + (a + a_a x_t) * G(t^*, \sigma_{t^*}; \hat{\gamma}, \hat{c})$$

Variable	Estimate	Standard Error	p-value
b_0	2729	588	0.6449
b_1	0.0998	0.0376	0.0104
a_0	7670	8100	0.3479
a_1	-0.0927	0.0554	0.1004
$\hat{\gamma}$	12.4310	29.8595	0.6789
$\hat{c}$	0.6524	0.0586	<0.0001

AIC: 1411.515

Panel 3.C: Threshold model of all wheat open interest on total stocks in the estimated form with y_t and x_t representing changes in total open interest and changes in total stocks, respectfully:

$$y_t = (b_0 + b_1 x_t) * (1 - d) + (a_0 + a_a x_t) * d + \varepsilon_t$$

Variable	Estimate	Standard Error	p-value
b_0	2092	5698	0.7149
b_1	0.0916	0.0341	0.0096
a_0	7637	7662	0.3233
a_1	-0.0841	0.0489	0.0911

AIC: 1408.308