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Modeling Acreage Response in a New Market Environment *

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Abstract

We pursue two distinct approaches to measuring the stability and validity of conventional approaches to measuring acreage response. Our focus is on corn and soybeans, which have perhaps been the most significantly impacted of the main commodities by market and policy changes. As noted, much of the change impacting commodity markets has been triggered by bio–energy policies, with ethanol from corn being the most prominent renewable fuel targeted by these policies. These policies have included ethanol tariffs and tax–credits for gasoline blenders. We first consider the structural stability of a standard acreage response model of the form often estimated in the empirical literature (see, for example, the seminal paper of Chavas and Holt (1990)). We apply structural change tests capable of identifying structural changes occurring at unknown break points and at the ends of a data series. The latter approach to testing is especially important in this application since the most substantial changes in markets have occurred since the 2007 Energy Independence Act. We then consider an analogous empirical evaluation of acreage response using panel data made up of annual observations taken at the crop reporting district (CRD) in the major corn producing states (i.e., the Corn Belt). We apply the newly developed inferential technique suggested by Cameron, Gelbach, and Miller (2011) that permits one to account for multi–dimensional clustering in panel data. Implications for modeling acreage response under changing market and policy conditions are discussed.

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Introduction

Acreage response modeling has a key role in applied policy analysis. Understanding how previous policies may have impacted acreage response can be an important tool in analyzing alternative proposed new policies or reforms of existing agricultural policies, leading to more informed agricultural policy implementation. A large body of empirical research has investigated models of acreage response to changes in prices, risk, and other market factors. U.S. agricultural markets have experienced profound changes in recent years. Prices have reached unprecedented highs and markets have experienced sustained levels of volatility not seen in recent history. For major U.S. row crops, price volatility has nearly doubled in recent years. A number of factors underlie such changes, including bioenergy policy, high energy prices, low stocks, and growth in international demand for fuel and feedstuffs. In addition, U.S. agricultural policy has undergone a number of changes over the last twenty years, including the planting flexibility afforded by the 1996 FAIR Act, the provision of counter-cyclical support through market loss assistance and counter-cyclical payments, and the introduction of the Average Crop Revenue (ACRE) program in 2008. A central question that becomes relevant in light of such significant market shocks is the extent to which existing estimates of acreage response may have under-gone structural changes and whether they are accurate enough to be used for current policy analysis. Two key questions of interest in this paper is to first examine whether structural change has impacted the determinants of U.S. corn and soybean acreage. The second is to address, based on empirical evidence of examining the first question, and is there more appropriate ways to specify models of acreage response.

If structural change occurs over the period of interest, due to policy or other market shocks (e.g. changes in market volatility), for which economic data is being employed to estimate important market parameters such as acreage responsiveness, the models may be misspecified and yield biased results. Estimated elasticities of acreage response based upon biased parameter estimates which in turn are used in modeling alternative proposed agricultural policy changes or reform can further manifest into misinformed or inappropriate estimated impacts that can result in erroneous policy changes being enacted. The potential of an underlying structural change for the period of interest, which has implications for estimating the central economic relationship, such as acreage response, presents a challenging and difficult empirical problem for applied economists. An important step in empirical analysis and model development is to first test for the presence of structural change and to identify potential break points or periods for which a structural change may have occurred. If inferences reveal periods of structural change or break points then important modeling choices must be made in an effort to try and avoid bias in parameter estimates but, at the same time, use as much of the applicable data as possible to maintain degrees of freedom. How to identify and then address structural change in modeling important relationships such as acreage response remains work in progress to applied agricultural economists. Substantial progress has been made beyond the standard Chow tests (Chow (1960)) which suffered from the need to specify a priori the break point under the alternative hypothesis, which is difficult and sometimes arbitrary without structural change tests capable of identifying changes occurring at unknown break points and at the end of data series (Andrews (1993); Hansen (1992), Ploberger and Karmer (1992)). As part of the contribution of this paper, we apply such structural change tests capable of identifying changes occurring at unknown break points and at the ends of a data series.

Potential remedies are to truncate the sample period to exclude periods of structural change. For example it might be appropriate to truncate a series and use the most recent observations if a substantial change in policy might have occurred-the 1996 Farm Bill is a potential example where it is likely appropriate (i.e. this needs to be confirmed empirically with inference using the above mentioned methods). This approach comes with trade-offs, however. That is, the benefit of eliminating potentially biased estimates must be weighed against the expense of reducing the degrees of freedom and potentially the precision of parameter estimates due to the truncated sample. Another approach if a particular break point can be identified with inference is to attempt to explicitly model this structural change using dummy variables or introducing other explanatory variables that are appropriate to account for the market shock responsible for the structural change. A third approach is to again truncate the sample period at the identified break point but to employ more disaggregated data using a panel data set-a time-series and cross-sectional approach-in an effort to offset the loss of degrees of freedom due to truncating the sample with the additional observations in a given year due to the disaggregation to a panel series. For example one could model Crop Reporting District (CRD) data as compared with annual data. As is often the case, this alternative brings its own new challenges with respect to modeling concerns with non-dependence within years and cross-sections that must be taken into account. In this paper we take up this challenge of the latter approach, by using the newly developed inferential technique suggested by Cameron, Gelbach, and Miller (2011) that permits one to account for multi-dimensional clustering in panel data and to investigate how this method impacts estimates of acreage response.

Modeling Approach

We pursue two distinct approaches to measuring the stability and validity of conventional approaches to measuring acreage response. Our focus is on corn and soybeans, which have been arguably the most significantly impacted of the main commodities by market and policy changes. As noted, much of the change impacting commodity markets has been triggered by bio–energy policies, with ethanol from corn being the most prominent renewable fuel targeted by these policies. These policies have included ethanol tariffs and tax-credits for gasoline blenders. We first consider the structural stability of a standard acreage response model of the form often estimated in the empirical literature (see, for example, the seminal paper of Chavas and Holt, 1990). We apply structural change tests capable of identifying changes occurring at unknown break points and at the ends of a data series. The latter approach to testing is especially important in this application since the most substantial changes in markets have occurred since the 2007 Energy Independence Act. We then consider an analogous empirical evaluation of acreage response using panel data made up of annual observations taken at the crop reporting district (CRD) level in the Corn Belt. We apply the newly developed inferential technique suggested by Cameron, Gelbach, and Miller (2011) that permits one to account for multi-dimensional clustering in panel data. Our corn and soybean acreage response models include output prices, input prices, a measure of farm wealth (net equity), and a measure of market volatility (the standard deviation of a harvest-time futures contract over the months immediately preceding planting).

The first segment of the analysis involves estimation of a standard acreage response function for U.S. total corn acreage. Annual data spanning the 1960-2010 period are used in the application. We apply three versions of cumulative sum-of-residuals empirical process tests. We first apply the conventional recursive, cumulative sum of standardized residuals test of Brown, Durbin, and Evans (1975). This test has become a standard tool for considering the structural stability of a regression model. However, because the critical values expand as one proceeds through the residual series, the test may lack power in identifying structural breaks that occur late in the sample-a situation that is particularly applicable to our consideration of structural changes in agricultural markets. We present two versions of the OLS-residual-based cumulative sum tests following the approach of Ploberger and Kramer (1992). Ploberger and Kramer (1992) demonstrate that this test may offer substantial power advantages in identifying structural breaks. A third version of our test utilizes these alternative critical values. All of the cumulative sum tests confirm the presence of significant structural breaks in the annual, aggregate data series. The sup (F) test of Andrews (1993) is used to confirm the structural breaks.

On the basis of the aggregate model results, we consider an alternative specification that is estimated using a panel of data constructed from CRD-level observations of corn acreage for the 1970-2010 period. Because of the presence of unobserved heterogeneity and the potential for clustering effects, we estimate a fixed-effects model (with fixed-effects for each CRD) and also apply the two-way robust clustering techniques recently introduced by Cameron, Gelbach, and Miller (2011).

Data

Table 1 presents the summary statistics for both the aggregate U.S. annual data spanning the 1960-2010 period and also the CRD-level annual data spanning the 1970-2010 period. The former series is applied in the first segment of the paper with corresponding regression results appearing in Table 2 and Figures 1 and 2. The latter is used in the second segment of the paper with corresponding regressions results appearing in Table 3. The first panel of Table 1 reveals over the period 1960-2010 aggregate US average corn acres were 76.1 million acres and soybean acres were 58.4 million acres. The real fertilizer prices index (with 1990-1992=100) averaged 217 but varied significantly with a standard deviation of 61 (about 28% of its average value) and exhibited a range of almost four-fold with a minimum value of 130.91 and maximum value of 397.01. The summary statistics of the expected corn price measured as the average of the new crop corn futures at planting measure (using the average of the December corn futures of the corresponding crop year traded in February) exhibits the above-mentioned price volatility with a mean value of $2.38 per bushel but with a low of $0.91 per bushel and a high of $5.40 per bushel. Similarly, the expected soybean price measured as the average of the new crop soybean futures at planting, measured as the average of the November soybean futures of the corresponding crop year traded in February, exhibited unprecedented volatility with a mean value of $5.48 per bushel but with a low of $2.08 per bushel and a high of $13.36 per bushel. The underlying volatility of the corn and soybean prices is also captured and formally included as an explanatory variable measured by the standard deviation of February daily returns for the respective harvest futures contract (December for corn and November for soybeans). Table 1 reveals the range of the volatility of futures prices averaging 0.02 but ranging from nearly 0.00 to 0.09 for corn and for soybeans averaging 0.2 with a slightly smaller range of 0.00 to 0.06.

The second panel of Table 2 reveals over the period 1970-2010 the annual observations taken at the crop reporting district (CRD) in the Corn Belt averaged 881 thousand acres of corn and 655 thousand acres of soybeans. The CRD level analysis revealed a real fertilizer prices index averaging 217.34 with, again, significant variation. The truncated CRD-analysis sample which did not include the first 10 years of 1960-1969 led to slightly higher expected average corn and soybean prices of $2.67 and $6.20 per bushel, respectively, however the significant levels of volatility as measured by the standard deviations and range are of similar magnitudes as those in the aggregate US sample. This is consistent with the above-mentioned significant price volatility having occurred more recently.

Results

Standard OLS Models

The first segment of the analysis involves estimation of a standard acreage response function for U.S. total corn and soybean acreage using standard OLS estimates with results shown in Table 2 and tests of structural change using these data in Figure 1 and Figure 2. The estimated aggregate US corn and soybean acreage response models in Table 2 (following Chavas and Holt, 1990) include expected corn and soybean prices as measured by the average February quotes of harvest time futures contracts. We consider two different approaches; including these prices as ratios and as separate, real prices. The first approach, as shown in the first panel in Table 2, includes the prices as corn price/soybean price. This offers the advantage of not needing to choose a deflator but assumes symmetry in elasticities. The second approach, shown in the second panel in Table 2, includes prices expressed as real prices where the expected corn and soybeans prices are each divided by the consumer price index to convert them to real prices. Other explanatory variables used in both approaches for these aggregate models include input prices as measured by real fertilizer prices, a wealth variable as measured by real equity of the farm sector and the price volatilities of new crop futures in February for both corn and soybeans. The most striking result with respect to the aggregate annual models as OLS estimates is that they reveal there are no statistically significant price-acreage effects with one exception: the real corn prices have a negative and statistically significantly different impact in the soybean acreage equation. This lack of statistical significance of price combined with poor model fit (for the corn equations R squares were less than 0.5) is consistent with presence of unaccounted for structural change over the period 1960-2010. Other explanatory variables are statistically significant and are consistent with expectations, such as higher fertilizer prices reduce corn and soybean acreage and there is a positive effect of wealth on corn and soybean acreage. The aggregate models also suggest that there is not strong evidence to support the hypothesis that volatility in corn prices have an own- or cross-effect on either corn or soybean acreage with none of the estimated coefficients being statistically significant. The volatility of soybean prices is found to have a positive and statistically significant effect on both corn and soybean acreage in the models where prices as are specified as a ratio and in the soybean acreage models with real prices.

To investigate the presence of structural change over the period 1960 and 2010 we apply three versions of cumulative sum-of-residuals empirical process tests (cusum) for corn (see figure 1) and soybeans (see figure 2), respectively. We first apply the conventional recursive, cumulative sum of standardized residuals test of Brown, Durbin, and Evans (1975). This test has become a standard tool for considering the structural stability of a regression model. However, because the critical values expand as one proceeds through the residual series, the test may lack power in identifying structural breaks that occur late in the sample-a situation that is particularly applicable to our consideration of structural changes in U.S. agricultural markets. We present two versions of the OLS-residual-based cumulative sum tests following the approach of Ploberger and Kramer (1992). Ploberger and Kramer (1992) demonstrate that this test may offer substantial power advantages in identifying structural breaks. A third version of our test utilizes these alternative critical values.

The three charts in Figure 1 which illustrate the structural change tests for corn confirm the presence of structural change for the aggregate corn acreage response. The recursive cusum chart in panel (a), reveals that the empirical fluctuations are increasing over the sample analyzed and consistently exceed the critical 10% value band in the latter half of the sample. The OLS cusum chart in panel (b), reveals that empirical fluctuations of the test statistic in the mid-sample meet the 10% critical value. Finally, Hansen's sup(F) test confirms the presence of structural change in the early to mid-point of the sample for corn acreage response. The three charts in Figure 2 which illustrate the structural change tests for soybeans reveal strong support for the presence of structural change for the aggregate soybean acreage response. The recursive cusum chart in panel (a), reveals empirical fluctuations that increasing over the sample but do not exceed the critical 10% value ban. However, the OLS cusum chart in panel (b), reveals that empirical fluctuations in the mid-sample are statistically significant at the 10% critical value and Hansen's sup(F) test confirms the presence of structural change in the early to mid-point of the sample for soybean acreage response. In sum, for both the aggregate US corn and soybean acreage response models the cumulative sum tests confirm the presence of significant structural breaks and the sup (F) test of Andrews (1993) is used to confirm the structural breaks.

Fixed Effects, OLS, and Multi–Way Clustered Corrected CRD–Level Models

Based on the standard OLS aggregate models suggesting statistically significant structural changes, generally a poor fit, and acreage-price responses that are not statistically significantly different from zero we consider an alternative specification that might better account for the structural change. The choice made was to consider pooling data to form a panel and use a shorter time series (based on significant structural change test revealed in the earlier years up to mid-sample) in a fixed effects model. We considered CRD-level data for selected Corn Belt States of Iowa, Illinois, Indiana, Minnesota, Kansas, and Nebraska over the period 1970-2007. The choice of pooling raises concerns about non-independence across years and cross-sectional units. Cameron, Gelbach and Miller (2011) succinctly describe the concerns as "controlling for clustering can be very important, as failure to do so can lead to massively under-estimated standard errors and consequently over-rejection using standard hypothesis test" (pg 2).

Cameron, Gelbach, and Miller (2011) advanced the sandwich-type robust estimators for one-way clustering of Arellano (1987) to multiple dimensions by establishing an appropriate covariance matrix for the two way case. The critical insight and contribution of their work was to establish in the two-way case, the appropriate covariance matrix is the sum of the Arellano covariance matrices for one-way clustering in the time and cross-sectional dimensions and the negative value of Arellano's estimator simultaneously corrected for both time and cross-sectional clustering. We implement this methodology by estimating a fixed effects acreage model specification employing the CRD level data by contrasting OLS estimates and appropriately taking account of clustering in the time (over the period 1970-2007) and cross-sections by CRD (for the Corn Belt) allowing for robust inferences having taken account of the multi-way clustering (concerns of non-independence across years and cross-sections units) stated as corrected t values in Table 3.

The most striking feature of the results shown in Table 3, which compares a conventional fixed effects acreage response model using panel (OLS) versus the multi-way clustered corrected t-ratios, is the proposition that annual aggregate models massively understate standard errors is confirmed. The ratio of corn to soybean price model for corn reveals a statistically significantly different from zero impact of corn prices on acreage. Our results imply corn price-acreage elasticities of about 0.21 when structural changes are accounted for and the CRD level data are used in estimation. In contrast, the annual model does not reveal a statistically significant price effect. This provides further evidence of the effects of structural changes. Our results also demonstrate the potential hazards associated with ignoring multi-way clustering in models estimated using panel data. The standard errors of a standard fixed-effects model are substantially understated when clustering is ignored. In the real price models we found that soybean prices have a negative and statistically significant effect on corn acreage. Unfortunately the soybean own-price effect is the wrong sign (a sign of potential misspecification being present) but not statistically significantly so. Again it established that there is a negative and statistically significant influence of high fertilizer on corn and soybean acres and that there is positive influence of the wealth effect on corn and soybean acres. Statistically significant wealth effects have been noted in other research (e.g., Chavas and Holt, 1990) and suggest that agents may exhibit decreasing absolute risk aversion (DARA) preferences.

Finally, the results suggest that volatility of corn prices do not have statistically significant impacts on corn or soybean acreage whereas as soybean price volatility is consistently positive and statistically significant on soybean acreage across in both models but does not statistically significantly impact corn acreage. In sum, comparison of the OLS and multi-clustered corrected t- ratios suggested to researchers to exhibit a great deal of caution when working with panels using conventional fixed effect models as inferences are significantly impacted with the former resulting in massively understated standard errors which inflate t-values.

Conclusions

This paper has attempted to address two critically important and challenging problems facing applied agricultural economists interested in modeling acreage response with respect to two of the most important row crops in the US corn and soybeans. The first key question is whether structural change has impacted the determinants of U.S. corn and soybean acreage, and the second is to address, based on empirical evidence of examining the first question, if there are more appropriate ways to specify models of acreage response. The empirical analysis presented in this paper has made several noteworthy contributions. First using state-of-the-art inference methods it is established that structural change is present in both acreage response for corn and soybeans in the US over the period 1960-2010. This problem of empirically specifying and estimating a model to measure acreage response is further accentuated by the challenging fact that because most row crops are annual, there is only one observation per year and so establishing sufficient observations during a period where structural change is not present is challenging.

The models and analysis presented in this paper along with current market conditions suggest that acreage response will continue to be challenging due to the inherent problem of structural change and yet another shifting policy shift (2012 Farm Bill remains uncertain but current alternatives being considered involve significant reform). Following the approach adopted in this paper adopting shorter panels to address the concern of structural change over time but at the same time employing a disaggregated analysis at, say, the CRD level offers some promise. Because of the recent valuable contribution of Cameron, Gelbach, and Miller (2011) multi-way clustering can be addressed and lead to more robust inferences with respect to structural change by employing shorter panels that can avoid structural change and also appropriately take account of pooling concerns and non-independence across years and cross-sectional units. If the results presented in this analysis comparing OLS and multi-way clustering corrected t-ratios to previous work that has ignored clustering effects have likely produced misleading inferences with greatly underestimated standard errors.

Table 1. Variable Definitions and Summary Statistics

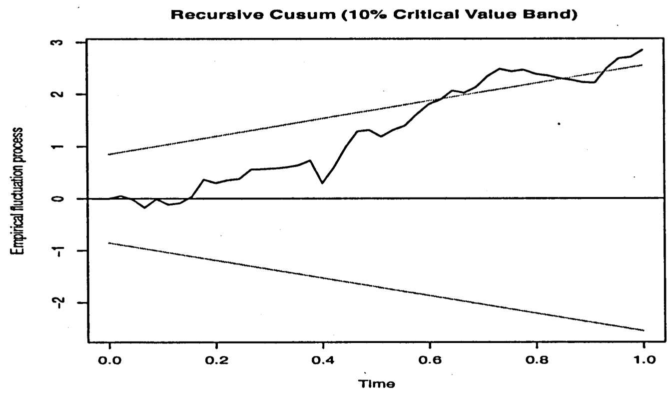
Variable	Mean	Std. Dev.	Min	Max
Aggregate US Analysis				
US Corn Acres (millions)	76.12	7.49	60.21	93.53
US Soybean Acres (millions)	58.39	14.96	24.44	77.45
Real fertilizer prices (1990-1992=100)	217.34	61.24	130.91	397.01
Expected corn price (Feb. quote of Dec. contract)	2.38	0.91	1.10	5.40
Expected soybean price (Feb. quote of Nov. contract)	5.48	2.22	2.08	13.36
Real corn prices	5.97	2.55	2.59	12.79
Real soybean prices	13.46	5.45	5.45	27.86
Ratio of corn to soybean prices	0.44	0.05	0.34	0.53
Real equity of farm sector	1,473.29	334.51	1,119.04	2,304.19
Volatility of corn prices (std. dev. of Feb daily returns)	0.02	0.02	0.00	0.09
Volatility of soybean prices (std. dev. of Feb daily returns)	0.02	0.01	0.00	0.06
CRD-Level Analysis				
Corn Acres (thousands)	881.33	595.00	0.10	2,250.00
Soybean Acres (thousands)	655.06	479.10	0.10	1,798.00
Real fertilizer prices (1990-1992=100)	203.18	57.71	130.91	397.01
Expected corn price (Feb. quote of Dec. contract)	2.67	0.76	1.17	5.40
Expected soybean price (Feb. quote of Nov. contract)	6.20	1.80	2.50	13.36
Real corn prices	5.30	2.45	2.36	12.79
Real soybean prices	12.28	5.55	4.98	27.86
Ratio of corn to soybean prices	0.43	0.05	0.32	0.56
Real equity of farm sector	1,528.90	344.61	1,135.46	2,304.19
Volatility of corn prices (std. dev. of Feb daily returns)	0.02	0.02	0.01	0.09
Volatility of soybean prices (std. dev. of Feb daily returns)	0.02	0.01	0.00	0.06

Table 2. Standard OLS Estimates of Aggregate US Corn and Soybean Acreage Response

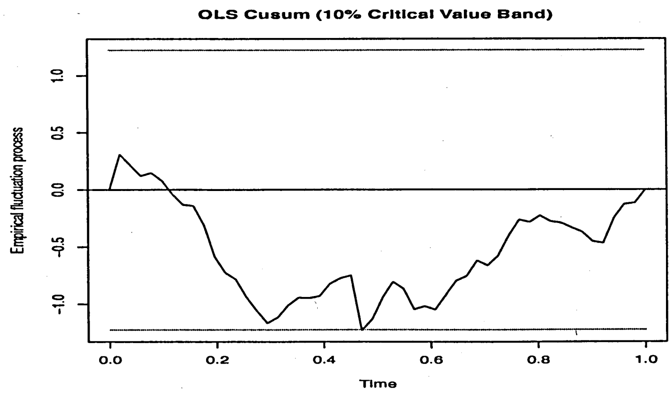
	Corn			Soybeans		
Variable	Parameter Estimate	Std. Error	t	Parameter Estimate	Std. Error	t
With Ratio of Prices						
Intercept	3.4053	0.4611	7.39	2.6079	0.8130	3.21
Ratio of corn to soybean prices	0.2000	0.1156	1.73	−0.1492	0.2038	−0.73
Real fertilizer prices	−0.1093	0.0469	−2.33	−0.8274	0.0828	−10.00
Real equity of farm sector	0.2227	0.0656	3.39	0.7677	0.1157	6.63
Volatility of corn prices	−0.4369	0.9438	−0.46	−2.3091	1.6644	−1.39
Volatility of soybean prices	2.7789	1.1313	2.46	8.6291	1.9950	4.33
R^2		0.4242			0.8051	
With Real Prices						
Intercept	2.9620	0.5233	5.66	1.2783	0.8648	1.48
Real corn prices	0.1147	0.1241	0.92	−0.4049	0.2052	−1.97
Real soybean prices	−0.1924	0.1134	−1.70	0.1719	0.1874	0.92
Real fertilizer prices	−0.0080	0.0758	−0.11	−0.5238	0.1253	−4.18
Real equity of farm sector	0.2276	0.0644	3.53	0.7824	0.1065	7.35
Volatility of corn prices	0.0506	0.9696	0.05	−0.8469	1.6025	−0.53
Volatility of soybean prices	1.9304	1.2185	1.58	6.0842	2.0139	3.02
R^2		0.4590			0.8392	

Table 3. Fixed Effects Model Estimates of Corn and Soybean Acreage Response: OLS and Multi-Way Clustered Corrected t-Ratios

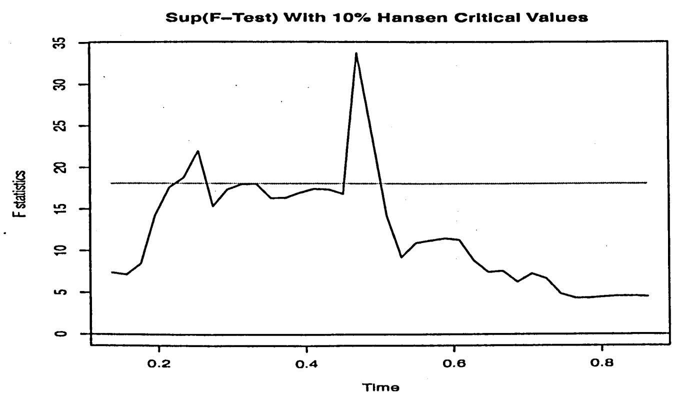
	Corn				Soybeans			
Variable	Parameter Estimate	Std. Error	OLS t	Corrected t	Parameter Estimate	Std. Error	OLS t	Corrected t
With Ratio of Prices								
Ratio of corn to soybean prices	0.3406	0.0499	6.82	2.32	0.4980	0.1216	4.09	1.43
Real fertilizer prices	−0.2945	0.0359	−8.20	−2.50	−1.7973	0.0853	−21.06	−5.48
Real equity of farm sector	0.2802	0.0366	7.65	3.16	0.6005	0.0871	6.90	2.55
Volatility of corn prices	−0.2338	0.4319	−0.54	−0.19	−1.8997	1.0465	−1.82	−0.62
Volatility of soybean prices	2.0055	0.5758	3.48	1.46	7.8992	1.4070	5.61	2.14
R^2		0.97				0.90		
F-test of CRD Fixed Effects		1,165.83				302.55		
With Real Prices								
Real corn prices	0.1425	0.0586	2.43	0.97	−0.4842	0.1368	−3.54	−1.51
Real soybean prices	−0.3191	0.0496	−6.44	−2.41	−0.4041	0.1160	−3.48	−1.82
Real fertilizer prices	0.0428	0.0642	0.67	0.40	−0.1092	0.1491	−0.73	−0.76
Real equity of farm sector	0.2275	0.0372	6.11	2.99	0.3289	0.0853	3.86	3.52
Volatility of corn prices	−0.0780	0.4282	−0.18	−0.07	−1.9164	0.9964	−1.92	−1.13
Volatility of soybean prices	1.5207	0.5752	2.64	1.09	6.5704	1.3433	4.89	2.07
R^2		0.97				0.91		
F-test of CRD Fixed Effects		1,189.70				333.74		



(a) Recursive CUMSUM Test

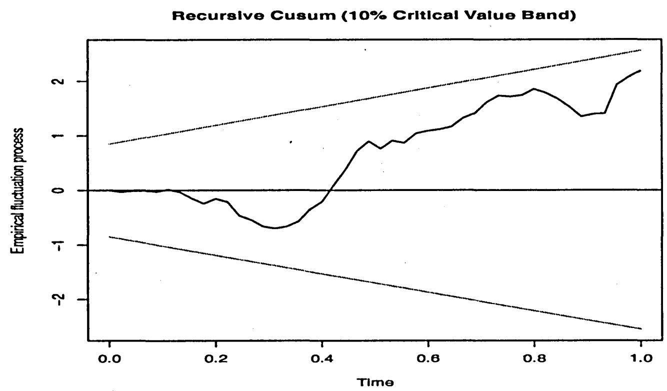


(b) OLS CUMSUM Test

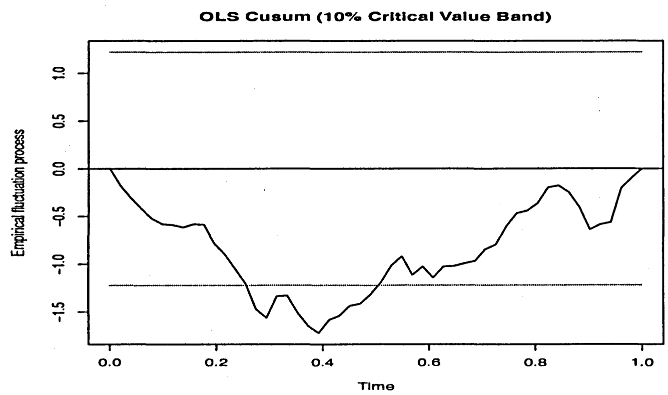


(c) Hansen's sup(F) Test

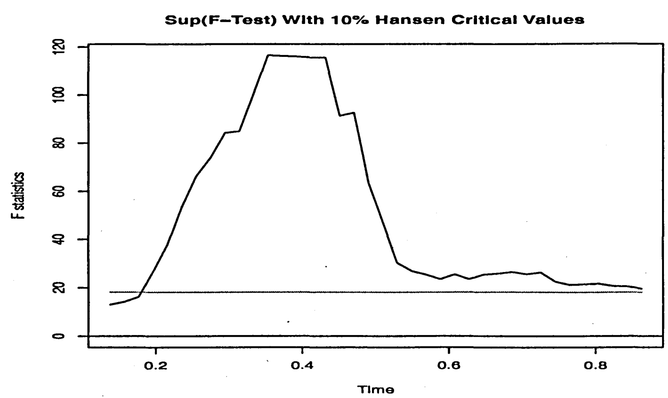
Figure 1: Structural Change Tests Results: Corn



(a) Recursive CUMSUM Test



(b) OLS CUMSUM Test



(c) Hansen's sup(F) Test

Figure 2: Structural Change Tests Results: Soybeans

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