Commodity Prices and Unit Root Tests

Dabin Wang and William G. Tomek

Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management
St. Louis, Missouri, April 19-20, 2004

Graduate student and Professor Emeritus in the Department of Applied Economics and Management at Cornell University.
Warren Hall, Ithaca NY 14853-7801
e-mails: dw66@cornell.edu and wgt1@cornell.edu

Commodity Prices and Unit Root Tests

Abstract *Endogenous variables in structural models of agricultural commodity markets are typically treated as stationary. Yet, tests for unit roots have rather frequently implied that commodity prices are not stationary. This seeming inconsistency is investigated by focusing on alternative specifications of unit root tests. We apply various specifications to Illinois farm prices of corn, soybeans, barrows and gilts, and milk for the 1960 through 2002 time span. The preponderance of the evidence suggests that nominal prices do not have unit roots, but under certain specifications, the null hypothesis of a unit root cannot be rejected, particularly when the logarithms of prices are used. If the test specification does not account for a structural change that shifts the mean of the variable, the results are biased toward concluding that a unit root exists. In general, the evidence does not favor the existence of unit roots.*

Keywords: commodity price, unit root tests.

Introduction

An understanding of the time-series properties of agricultural product prices is a prerequisite to analyzing risk management and forecasting problems. Structural models of commodity markets usually assume that the random variables are stationary. Their dynamic behavior is based *inter alia* on how expectations are formed relative to production and storage decisions, and the price theory underlying these models, including the assumption of efficient markets, does not require that time series of cash prices have a unit root (Tomek, 1994). Moreover, when nominal prices of U. S. farm commodities are plotted against time, they do not appear to have a unit root, at least not over the past 40 or 50 years.

Yet, test results are sometimes consistent with the existence of unit roots in commodity prices. Such studies have used data for different commodities, sample periods, and frequency of observations, as well as nominal and deflated prices and the logarithms of these prices. A variety of test specifications have been used.

The objective of this paper is to try to better understand the reasons for the diverse test results. It is unlikely, in our view, that cash prices for agricultural commodities follow a random walk. If this is so, then results that imply otherwise may be the consequence of specification errors. The equation used to test the hypothesis must be consistent with the underlying data generating process (for observations relevant to the research problem). Thus, we examine the consequences of alternative specifications.

The paper is organized as follows. We first characterize the empirical literature on tests for unit roots in commodity markets. Then, alternate tests and related specification issues are summarized. Next, we discuss the data and tests used in the paper. Finally, we present the empirical results and summarize our conclusions.

Literature Review

With the development of the literature on error correction models, co-integration, and unit root tests, applications to commodity prices became quite common. The early work led to the view that commodity price series exhibit non-stationarity, e.g., Ardeni's (1989) paper, *Does the Law of One Price Really Hold for Commodity Prices?*. He tested for unit roots in the import / export prices of wheat, wood, beef, sugar, tea, tin and zinc for four countries (Australia, Canada, UK, and USA) using an augmented Dickey-Fuller (ADF) test with quarterly observations from the mid-1960s through the mid-1980s. The null hypothesis, that a unit root exists, could not be rejected with the exception of UK tin prices.[1] In this context, using a co-integration approach consistent with the presumed non-stationarity of the variables, Ardeni concluded that the "law of one price" failed.

The empirical evidence for and against unit roots in commodity prices is based on a variety of sample periods, frequencies of observations, test specifications, and data transformations, and as the literature has grown, the results seem to have become more diverse. In a study of the effect of money supply on prices in New Zealand, Robertson and Orden (1990) found that money supply (M1), manufacturing prices (IP), and agricultural prices (FP) contained unit roots. They use quarterly observations from 1964.1 through 1987.1, and the data are transformed to logarithms. The ADF tests are based on equations with a constant and linear trend term-the ADF linear trend specification. The unit-root hypothesis can not be rejected at the 0.10 level for any of the series.

Babula, Ruppel, and Bessler (1995) analyzed the effect of the exchange rate on U.S. corn exports. The variables used in the analysis were monthly observations, from 1978.02 through 1989.12, for the real U.S. exchange rate, the real price of corn, U.S. corn export sales, and U.S. corn shipments. All data were transformed to logarithms, and ADF tests were conducted for these series (in levels of the logarithms). The authors concluded that the exchange rate and the price series were integrated of order one. Thus, a VAR model was fitted to sales and shipments in levels and exchange rates and prices in differences. The authors mention that a structural change may have occurred in the price and exchange rate series in 1985.02, but this change does not appear to have been modeled in the tests for unit roots. The sub-periods are, however, used to analyze out-of-sample forecast performance.

In an analysis of weekly cattle prices at seven locations (Foster, Havenner and Walburger, 1995), for the sample period 1984.3 to 1987.2, the null of a unit root could not be rejected at the 0.05 significance level for the respective series. The authors concluded, however, that the prices likely contain a slow dynamic component rather than an exact unit root. This conclusion is based on an analysis of the spectrum of the time series.

A long-standing hypothesis is that agricultural product prices are declining relative to manufactured good prices. Analyses of the relationship of commodity to manufactured good (or wholesale) prices have used annual observations for long time periods (Cuddington and Urzua, 1989; Newbold, Rayner, and Kellard, 2000; Newbold and Vougas, 1996). Different tests and test specifications have been used,[2] and a variety of conclusions reached. Cuddington and Urzua, using a ratio of price indexes for the years 1900-1983, cannot reject the null that the ratio series has a unit root. Newbold and Vougas, using the logarithm of a similar ratio of indexes for the period 1900 - 1992, indicate that it is difficult to distinguish between the trend stationary and difference stationary (unit root) alternatives. In Newbold, Rayner, and Kellard, nominal prices of wheat and maize exports from the U.S. are deflated by alternative deflators, to obtain four series for the years 1900-1995. If the deflator is a price index of manufactured export goods, the null hypothesis of a unit root cannot be rejected. If the deflator is the wholesale price index, the results are less clear-cut, and the authors conclude that unit root tests are “unhelpful” in model selection.

Labys and colleagues explored the question, can commodity prices be characterized by fractal behavior (Barkoulas, Labys, and Onochie, 1997; Cromwell, Labys, and Kouassi, 2000)? Barkoulas et al. analyzed price series for 21 internationally traded commodities for the months 1960.01 through 1993.07. Several unit root tests were implemented for the log level of each price series, and then a fractional integration test was applied to the differences of the logarithms of the series. In 16 of 21 cases, the hypothesis of a unit root could not be rejected, and they found evidence that favored fractal integration for six price series.

In the 2000 paper, which appears to use 15 of the 21 series considered in the 1997 paper, Cromwell, Labys, and Kouassi were “surprised” to find that the null hypothesis of a unit root could not be rejected. This surprise perhaps arose because they used an alternative, presumably more powerful, test for unit roots than had been applied in the 1997 paper. Based on further analysis and tests, they concluded (p. 576) “Although some [prices] are mean reverting, it is clear that all possess increasing variances. .. [and] .. (p. 577) all commodity spot prices do possess a persistence component which is manifested in an infinite variance.

In an analysis of soybean and corn futures prices,[3] Lordkipandize (2004, p. 82) concludes “seasonality and maturity effects appear to be the primary drivers of volatility. The long-memory effect is secondary.” Admittedly, she was studying different prices (with different methods) than Labys and colleagues, but her results cast doubt on characterizing commodity price behavior as having infinite variances. Thus, we are less sanguine than Cromwell, Labys, and Kouassi that they have found generalizations about price behavior that can be applied to future realizations of commodity prices. At a minimum, one can say that the empirical results are mixed and that the results of unit root tests do not provide obvious generalizations about the time-series properties of commodity prices.

Alternate Tests and Their Specification

Tests for unit roots have proliferated since the pioneering work of Dickey and Fuller. This section briefly describes selected tests. Additional details are provided in Appendix I. The next section further discusses the effects of alternate specifications on test results.

Augmented Dickey-Fuller (ADF) Tests

A variety of set-ups exist for the Dickey and Fuller (1981) test equation. The dependent variable can be specified as a level or as a first difference. If the dependent variable is a first difference and if the right-hand side variable is the lagged level, the null hypothesis is that its parameter is zero. Thus, the null is that the time-series variable has a unit root and the alternative is that the series is stationary. The equation can be estimated by OLS, but the test statistic (tau) has a non-standard probability distribution. Dickey and Fuller provide critical values for the test.

The test result is, of course, conditional on the remaining specification of the right-hand side. Since economic time series may contain a secular trend, a constant term is usually included in the equation. A linear deterministic trend variable may also be included, particularly when the dependent variable is not differenced. In addition, lags of the first-difference of the variable may be included to account for autocorrelation that may be present in the error term. One wants the error term to be "white noise." The specification issues include whether or not to include the linear trend and the lagged differences, and the length of lags if any.

The test has problems. It has low statistical power to reject a unit root, and power is reduced with the addition of the lagged differences. The ADF test is also plagued by size distortions that occur when a large first-order moving average component exists in the time series. Diebold and Rudebusch (1991) show that the test has low power against the alternative of fractionally integrated series. Perron (1989, 1993) show that when a time series is generated by a process that is stationary about a broken trend, standard DF tests of an I(1) null may have very lower power. On the other hand, Leybourne, Mills and Newbold (1998) show that when a time series is generated by a process that is I(1), but with an abrupt break, routine application of the DF test can lead to a severe problem of spurious rejection of the null when the break is early in the sample period.

Phillips-Perron (PP) Test

Since Dickey and Fuller published their tests, many other tests have been proposed. The Phillips and Perron (1988) statistic can be computed using the same equation specifications as in Dickey and Fuller, with the dependent variable in level form. Thus, the null hypothesis of the PP test is also that a unit root exists, as against the alternative of stationarity. The estimated coefficients from the regressions are modified to obtain Z statistics (see appendix I), and these statistics are referred to the Dickey-Fuller critical values. The intent of the PP test is to improve the finite sample properties of the ADF test.

Structural Change and Unit Root Tests

Perron (1989, 1990) and Perron and Vogelsang (1992b) have extended the ADF specification to allow for possible structural breaks in the time series. Perron's structure change test permits a break under both the null and alternative hypotheses. Perron's Additive Outlier

(AO) test assumes that the structural change occurs at a point in time, using zero-one variables to account for the break, i.e., a shift in the mean. The Innovational Outlier (IO) model assumes that the change affects the level of the series gradually. If a structural break has occurred, but is not modeled in the test equation, then the ADF test result is biased towards a false acceptance of a unit root.

Additional research has developed tests for the cases of more than one structural break in the series (Vogelsang, 1997), for the case when the date of the structural change is unknown (Perron and Vogelsang, 1992a, Christiano (1992), Zivot and Andrews (1992), Vogelsang and Perron, 1998), for the case when the break is in the innovation variance (Kim, Leybourne and Newbold, 2002), and for the case with seasonality and structural break (Busetti and Taylor, 2003). However, the unit root hypothesis may be falsely rejected, i.e., the result finds a spurious structural change (Chu and White, 1992, Nunes, Newbold and Kuan, 1996 and Bai, 1998).

Other Tests

Additional tests, not used in this paper, allow for other data generating processes or address the question of the existence of unit roots from different perspectives. For example, Elliot, Rothenberg, and Stock (1996) propose a test, ADF-GLS procedure that allows the error term of the test equation to have more general formulations. The error term is assumed to be an I(0) process, such as an ARMA (p, q) or a GARCH.

In Kwiatkowski, Phillips, Schmidt and Shin (1992), the time series is written as the sum of a deterministic trend, a random walk, and a stationary error term. Their test is based on the idea that the random walk component is not contributing to the variability of the data generating process. Leybourne and McCabe (1994) also propose a test that tries to discriminate between series that are trend stationary versus those with a unit root process; the null hypothesis is that the series is trend stationary and the alternative is a unit root process. In Ouliaris, Park, and Phillips (1989), the null hypothesis is the presence of a unit root in the series versus the alternative of stationarity around a deterministic polynomial trend. Smith and Taylor (1998), Busetti and Taylor (2003), Rodrigues and Taylor (2004) consider seasonal unit root tests.

Geweke and Porter-Hudak (1983) approach the problem in another way. They propose a nonparametric, spectral regression-based approach to estimate the order of integration. The standard tests, like ADF and PP, may have low power in the presence of fractionally integrated alternatives.

Specification Issues

Some practical issues in setting up the tests are addressed below. In addition to the questions of lag length, trend specification, and structural break, the analyst makes decisions about the sample period, frequency of observations, and data transformations. The conclusion from a test is conditional on (and likely sensitive to) the specification.

Data Transformations

The time-series variable being tested may be specified in nominal or real terms, and the variable is sometimes transformed to logarithms. The decision of whether or not to transform the data depends on the underlying research problem. What is the question being asked? Is it best answered by modeling the original series, the deflated series, the logarithm of the series, or the logarithm of the deflated series?

The original data may not have a unit root, but the transformed series may have. A casual inspection of graphs of nominal grain prices in the United States, observed over the last half century, suggests that they are stationary (see figures below). Consequently, deflating by a trending price index introduces a downward trend in real prices (Peterson and Tomek, 2003).

Data Frequency

Does the frequency of observations influence the conclusion drawn about the existence of a unit root? This question has received some attention (Choi, 1992; Ng, 1995; Perron, 1991; and Chambers, 2004), but the answer is not clear-cut. Perron (1991) assumes that the random variable has a basic underlying continuous time process with given parameters and that this process is sampled at discrete time intervals. The total number of observations (T) depends on the span (S) of the sample and the sampling frequency (1/h). T=S/h. One can ask about the consistency of the test results for varying h and about the power of the tests. The answers appear to depend, in part, on what is assumed about S as h changes.

A special case, that is perhaps common, is a fixed time span. In this case, if the frequency of observations is increased, say from monthly to weekly, T increases. Based on Monte Carlo simulations, it appears that the power of the particular test analyzing by Perron increases as the sampling frequency (and hence T) increases, with S fixed, but ultimately levels off. With a fixed span, the sampling interval, h, converges to zero at the same rate as the sample size increases to infinity, the limiting distribution under the null (of a unit root) and the alternative hypothesis are different and so the limiting power of the tests does not converge to the size of the test as the sample increases. The tests is bounded in probability under both the null and the alternative hypothesis; hence, the test is not consistent; varying the frequency of observations can cause the test to reach different conclusions about the existence of a unit root.[4] And the power of the tests are not monotonically increasing as h decreases. When considering flow data and varying sampling frequency (Chambers, 2004), the test consistency conclusion for this special case (fixed span and regression with an intercept) is in accordance with the results of Perron (1991).

If the assumption of a fixed S is relaxed, it appears that the span of the sample is more important than the number of observations in determining the power of the test. This, of course, assumes a constant structure (data generating process), but lengthening the sample period increases the probability that the sample spans a period with one or more changes in structure.

Specification of Lags and Structural Breaks

In conducting the ADF or similar tests, the analyst must specify *p*, the number of lagged variables, if any, to include in the test equation. If *p* is chosen too small relative to the true structure, then the inference about the existence of a unit root is biased (Schwert, 1989). If *p* is chosen too large, then the finite sample properties of the unit root test likely deteriorate, i.e., an inefficient estimate of the test parameter is obtained. Inferences about the existence of a unit root are sensitive to the choice of *p*.

Early applications did not include lagged variables. Recognizing that this might bias the test results, one strategy is to choose *p* to be "surely larger" than the true parameter, running some risk of reducing the efficiency of the estimator. The second, and more common, approach is to use the data to select *p*, i.e., to pretest.

It appears that in practice, many researchers use a general-to-specific strategy using t or F tests (Perron and Vogelsang 1992a). That is, they start with a large lag length and test down to a simpler specification. Some analysts have used a specific-to-general approach, perhaps with an information criterion as the basis for selection. These two approaches do not necessarily lead to the same asymptotic distribution for the test statistic. One wants the residuals to be white noise.

Hall (1994) argues that using the data to select *p* can result in a gain in power of the test for a unit root. In any case, it is probably inevitable that analysts will pretest, and the general-to-specific approach seems preferred.

If the sample spans a long time period, the analyst needs to be sensitive to the possibility of structural changes in the data generating process. It is best if the specification can be based on logic-on known causes and timing of the change. In some cases, a simple inspection of graphs can confirm the logic of a structural change. If uncertainty exists about the timing and nature of structural changes, statistical tests are available. Perron and Vogelsang (1992a), Vogelsang and Perron (1998) propose tests for a unit root allowing for a break in the level and the trend function, respectively, at an unknown time.

Data and Research Design

Our research design is to apply alternative specifications of the ADF and PP tests to various price series. The tests use monthly observations on prices, spanning September 1960 through August 2002, for corn and soybeans, and January 1960 through December 2002 for barrows and gilts and milk. In addition, we use weekly observations for corn and soybeans observed from September 1975 through December 2002. The weekly observations, provided by the University of Illinois, are believed to be of high quality. Thus, we also use monthly observations for Illinois, from the National Agricultural Statistics Service for purposes of comparison. The monthly data are plotted in Figures 1 through 4. Definitions of the variables are provided in Appendix II.

The tests are applied to nominal prices, to logarithms of the nominal prices, to prices deflated by the CPI, and to the logarithms of the deflated prices. Although the CPI is a commonly used deflator, it is not necessarily the appropriate one for particular research problems. The monthly CPI is displayed in Figure 5, and is clearly trending upward.

The tests are done with and without a linear trend, and we employ a general-to-specific method to obtain the lag specification. Thus, the results are believed to be consistent with conventional approaches to testing for unit roots.

In addition, possible changes in structure are considered. Points of structural change are identified by combining knowledge of the events influencing the structure and visual inspection of graphs. We compare results from the full sample to results from sub-periods, and also allow for structural break in the full samples. For corn and soybeans, test results are compared for weekly and monthly observations spanning the same time period (1975-2002). Details of test procedures are discussed further in appendix I.

Results

In the first sub-section, we report results for tests applied to the full sample of monthly observations, but not allowing for structural change. These results are viewed as those likely obtained from conventional practice. The second sub-section emphasizes the results obtained when allowing for structural change in the full sample or from dividing the sample into sub-groups.

Conventional Tests without Structural Change

Selected tau values for the ADF test for the four commodities are presented in Table 1. The upper part of the table illustrates the diverse results obtained for soybeans using different specifications. The bottom portion shows the results for the specification with linear trend and the optimal lag (based on a general to specific method), which is indicated in parentheses. The columns represent nominal, deflated, logarithm of nominal, and logarithm of the deflated prices. Additional information is provided in the table notes.

The following generalizations can be made. First, the null hypothesis of a unit root typically cannot be rejected when the logarithm of nominal prices is used. This data transformation makes a difference in the conclusion reached about unit roots. Second, the null generally can be rejected for the prices soybeans, corn, and barrows and gilts, when they are in nominal, deflated, or logarithm of deflated terms.[5] Third, the evidence is consistent with a unit root existing in milk prices. Milk prices appear to be difficult to model over the 43 year sample period, and to achieve white noise residuals for the test, 20 lags were required. As noted earlier, long lags in the test equation seem to be associated with not being able to reject the null.

Results for the comparable Phillips-Perron test are provided in Table 2. This test tends to "sharpen" the results relative to the ADF tests in a few cases. Namely, the estimated tau values tend to be larger in absolute value; thus, for given critical values, one is more likely to reject the null. But, the use of the PP test made little difference in the conclusions. It is still true that the null of a unit root cannot be rejected for the case of the logarithm of nominal prices.

In sum, it is clear that the results depend on the specification of the test. Thus, it is not surprising that different analysts can reach different conclusions. At the same time, the evidence favoring unit roots in commodity prices is not strong. Although conventional ADF test specifications are applied to long samples without modeling possible structural breaks, the null hypothesis of a unit root is rejected in the majority of cases.

Sample Span and Structural Change

Plots of the data, as well as knowledge of political events and policy changes, suggest that structural changes occurred in the data generating processes for the four commodities. One point of change is in 1973. This is the year that the (former) Soviet Union entered world markets, increasing the demand for commodities, particularly grains. As an aside, many of the papers in the literature use samples that span the year 1973, but do not allow for a possible structural change.

In table 3, we present tests based on splitting the data into two sub-periods. For soybeans, corn, and barrows and gilts, the ADF test typically rejects the null of unit root for the various commodities and sub-periods. The two exceptions are for the deflated and the logarithm of the deflated prices of corn in the 1960 to 1972 period.

Milk prices represent a more complex situation. A structural change appears to have occurred in 1973, but also at other points in time. Farm price policies in the United States changed importantly in the 1980s and 1990s, and perhaps had greater effects on the milk price structure than for other commodities. In addition to a possible change in 1973, we allow for a change in 1981.1. Policy changes may have also affected milk prices in 1984 and in 1989, but we do not model the recent changes. Thus, in Table 3, test results for milk are reported for three periods, 1960.1 - 1972.12, 1974.1 - 1980.12, and 1981.1 - 2002.12. The null hypothesis is rejected for the 1981.1 - 2002.12 period for all of the definitions of price. It is also rejected for the 1974.1 - 1980.12 period for all cases except nominal prices.

The results for monthly and weekly observations for corn and soybean prices can be compared for a more recent period, 1975 - 2002 (Table 4). Since weekly observations are not available for the CPI, the comparison is made only for nominal and the logarithm of nominal prices. The ADF test statistics tend to be somewhat smaller in absolute value for the weekly prices, but in all cases, the null of a unit root is rejected. The bottom portion of Table 4 illustrates that the conclusion-reject the null-is not sensitive to the selection of the lag length. This result is consistent with the frequency consistency conclusions drawn in the previous section: as the sampling frequency (and hence T) increases, with S fixed, the power increases, but ultimately levels off. The power of the tests are not monotonically increasing as h decreases. In our case, we have a fixed span of 27 years, and the frequency changes from monthly to weekly at a speed slower than T. The unit root conclusion is rejected by both cases. However, the power of the test using weekly data can be weaker than using monthly observation, that is, the absolute value of the weekly test statistics can be less than the monthly observation ones.

As an alternative to splitting the sample, we model the entire 1960 - 2002 sample while allowing for structural change. The results, for those cases where the null hypothesis was not rejected for the full sample, are reported in Table 5. The test equations are defined in the table footnotes; all of them allow for a change in the mean at a point in time. We also consider a specification that allows for a deterministic trend and a change in the slope of the trend at the point of structural change.

For corn, soybeans, and barrows and gilts, the structural change is assumed to occur between 1972.12 and 1973.1. The gamma parameter, associated with the dummy variable that allows for the shift in the mean, is statistically different than zero in all of the equations. We also report those cases in which the slope of the trend variable appears to have changed. The null hypothesis of a unit root is now rejected (see tau value in Table 5).

As discussed earlier, there appears to be more than one point of structural change in milk prices. Previously, we fitted two time periods, omitting the year 1973. For the pooled observations, we divided the data into two overlapping periods: 1960.01 - 1980.12 and 1974.01 - 2002.12. Then, within the first period, we assumed a structural change effective in 1973.1 and within the second period, we assumed a structural change effective in 1981.1.[6] With these definitions, the mean of prices appears to have changed significantly as does the slope of the linear trend variable. The null hypothesis of a unit root is now rejected. In other words, milk prices appear to be stationary, given the alternate approach to defining the sample span and structural change. At a minimum, the results make clear that selecting the sample period and defining points of structural change are likely important factors in the conclusions reached about unit roots.

The test equations used in this paper are, of course, not the only alternatives. All of the prices in our data set presumably have a seasonal component, and this likely explains the need for the lagged differences of prices in the model. Another approach to specifying tests would be to try to model seasonality. It is improbable, however, that the structure of the seasonal price patterns is a constant. That is, the amplitudes and timing of seasonal peaks likely are not a constants. Thus, the preferred approach to modeling seasonality is uncertain and could be a topic of further analysis.

Conclusions

We do not claim that our results are the “last word” about the existence of unit roots in cash price series for agricultural commodities. But, as noted in the introduction, no compelling theoretical reasons exist for finding unit roots in these series. Our results show that the specification of the test equation often influences the test outcome, which is a well-known phenomenon in hypothesis testing. Nonetheless, the consequence for tests for unit roots seems not to have been fully appreciated.

The data generating processes for commodity prices are complex. These price series are influenced by dynamic factors that create systematic behavior, with spikes, and by changes in farm and trade policies. Modeling commodity prices is not easy. Among other things, the effects of possible structural changes need to be considered, and this is especially true if the sample spans long periods of time.

End Notes

[1] The appendix of the article implies that series frequency is monthly, but the number of observations, as well as footnote 10, suggest that quarterly observations are used. The test specifies the dependent variable in differences with an intercept, but no linear trend term–the ADF simple mean specification.

[2] Cuddington and Urzua use the Perron (1989) test for unit roots where a shift in the mean is specified as occurring. Newbold and Vougas use a variety of tests. Newbold, Rayner, and Kellard use ADF and Leybourne-McCabe tests. In addition to these two tests, Ahrens and Sharma use the Perron test for unit root in the presence of structural change and the Ouliaris, Park, and Phillips test.

[3] The sample period is January 1989 to November 2000. Daily settlement prices are used for each futures contract, and implied volatilities are obtained from the options-on-futures premia for the nearest to at-the-money contracts.

[4]An analogous question arises in specifying distributed lag models. Will the analyst obtain consistent results about the form and length of lag, as the frequency of observations changes? The empirical evidence from this literature suggests not.

[5] Several test statistics are only slightly smaller, in absolute value, than the critical value (-3.13): -3.10 for the logarithm of the deflated soybean price and -3.11 for the logarithm of nominal corn prices. Given that the ADF test has relatively low statistical power, the evidence favoring a unit root is not strong in these cases.

[6] If the point of structural change is shifted to 1984.1, the conclusion is unchanged. No unit root appears to exist in the milk price data.

References

Ardeni,. P. G. "Does the Law of One Price Really Hold for Commodity Prices?" *American Journal of Agricultural Prices* 71 (August 1989): 661 - 669.

Babula, R. A., F. J. Ruppel, and D. A. Bessler. "U. S. Corn Exports: the Role of the Exchange Rate," *Agricultural Economics* 13 (1995): 75 - 88.

Bai, J., "A Note on Spurious Break." *Econometric Theory* 14 (1998): 663-669

Barkoulas, J. T., W. C. Labys, and J. Onochie. "Fractional Dynamics in International Commodity Prices," *Journal of Agricultural Economics* 51 (April 1997): 161 - 189.

Busetti, F. and A. M. R. Taylor. "Testing Against Stochastic Trend and Seasonality in the Presence of Unattended Breaks and Unit Roots." *Journal of Econometrics* 117(1) (2003): 21-53.

Chambers, M. J. "Testing for Unit Roots with Flow Data and Varying Sampling Frequency." *Journal of Econometrics* 119(1) (2004): 1-18.

Choi, I., "Effects of Data Aggregation on the Power of Tests for a Unit Root." *Economics Letters* 40 (1992): 397-401.

Christiano, L.J., "Searching for a Break in GNP" *Journal of Business and Economic Statistics* 10 (1992): 237-250

Chu, C.S.J., White, H., "A Direct test for Changing Trend." *Journal of Business and Economic Statistics* 10 (1992): 289-299

Cromwell, J. B., W. C. Labys, and E. Kouassi. "What Color are Commodity Prices: A fractal Analysis," *Empirical Economics* 25 (December 2000): 563 - 580.

Cuddington, J. T., and C. M. Urzua. "Trends and Cycles in the Net Barter Terms of Trade: A New Approach," *Economic Journal* 99 (June 1989): 426 - 442.

Dickey, D. and W. Fuller. "Likelihood Ratio Tests for Autoregressive Time Series with a Unit Root," *Econometrica* 49 (1981): 1057 - 1072.

Diebold, F. X., and G. D. Rudebusch. "On the Power of Dickey-Fuller Tests against Fractional Altenatives," *Economic Letters* 35 (1991): 155 - 160.

Elliot, G., T. Rothenberg, and J. Stock. "Efficient Tests for an Autoregressive Unit Root," *Econometrica* 64 (1996): 813 - 836.

Foster, K. A., A. M. Havenner, and A. M. Walburger. "System Theoretic Time-Series Forecasts for Weekly Live Cattle Prices," *American Journal of Agricultural Economics* 77 (November 1995): 1012 - 1023.

Geweke, J., and S. Porter-Hudak. "The Estimation and Application of Long Memory Time Series Models," *Journal of Time-Series Analysis* 4 (1983): 221 - 238.

Hall, A., "Testing for a Unit Root in Time Series with Pretest Data-Based Model Selection," *Journal of Business and Economic Statistics* 12 (1994): 461 - 470.

Hamilton, J. D. *Time Series Analysis.* Princeton University Press, 1994.

Kim, T.-H., S. Leybourne, et al. "Unit Root Tests with a Break in Innovation Variance." *Journal of Econometrics* 109(2) (2002): 365-387.

Kwiatkowski D., P. C. B. Phillips, P. Schmidt, and Y. Shin. "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root: How Sure Are We that Economic Time Series Have a Unit Root?" *Journal of Econometrics* 54 (1992): 159 - 178.

Leybourne, S. J., and B. P. M. McCabe. "A Consistent Test for a Unit Root," *Journal of Business and Economic Statistics* 12 (1994): 157 – 16

Leybourne, S. J., T. C. Mills, et al. "Spurious Rejections by Dickey-Fuller Tests in the Presence of a Break Under the Null." *Journal of Econometrics* 87(1) (1998): 191-203.

Lordkipanidize, N. *Modeling and Estimation of Long Memory in Stochastic Volatility: Application to Options on Futures Contracts.* PhD Dissertation, Cornell University, January 2004.

Marriott, J. and P. Newbold. "The strength of evidence for unit autoregressive roots and structural breaks: A Bayesian perspective." *Journal of Econometrics* 98(1) (2000): 1-25.

Newbold, P., T. Rayner, and N. Kellard. "Long-Run Drift, Co-Movement and Persistence in Real Wheat and Maize Prices," *Journal of Agricultural Economics* 51 (January 2000): 106-121.

Newbold, P., and D. Vougas. "Drift in the relative price of primary commodities: a case where we care about unit roots," *Applied Economics* 28 (June 1996): 653 - 651.

Ng, S. (1995), "Testing for unit roots in flow data sampled at different frequencies." *Economics Letters* 47: 237-242.

Nunes, L. C., P. Newbold, and C. Kuan. "Spurious Number of Breaks," Economics Letters 50 (1996): 175-178.

Ouliaris S., J. Y. Park, and P. C. Phillips. "Testing for a Unit Root in the Presence of a

Maintained Trend," *Advances in Econometrics and Modeling* , B. Raj, editor. Kluwer Academic, 1989.

Perron, P., "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis," *Econometrica* 57 (November, 1989), 1361-1401.

Perron, P., "Testing for a Unit Root in a Time Series with a Changing Mean," *Journal of Business and Economic Statistics* 8 (1990): 153 - 162.

Perron, P., "Test Consistency with Varying Sample Frequency," *Econometric Theory* 7 (1991): 341 - 368.

Perron, P. and T. J. Vogelsang. "Non Stationarity and Level Shifts with an Application to Purchasing Power Parity," *Journal of business and Economic Statistics* 10 (1992a): 301-320.

Perron, P., and T. J. Vogelsang. "Testing for a Unit Root in a Time Series with a Changing Mean: Corrections and Extensions," *Journal of Business and Economic Statistics* 10 (1992b): 467-470.

Perron, P., "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis: Erratum." *Econometrica* 61, 248-249

Vogelsang, T. J. "Wald-type Tests for Detecting Breaks in the Trend Function of a Dynamic Time Series," *Econometric Theory* 13 (1997): 818-849

Vogelsang, T. J. and P. Perron. "Additional Tests for a Unit Root Allowing for a Break in the Trend Function at an Unknown Time," *International Economic Review* 39 (1998): 1073 - 1100.

Peterson, H. H., and W. G. Tomek. "Consequences of Erroneous Deflators," Kansas State University, manuscript, 2003.

Phillips, P. and P. Perron. "Testing for a Unit Root in Time Series Regression," *Biometrika* 75 (1988): 335 - 346.

Robertson, J. C., and D. Orden. "Monetary Impacts on Prices in the Short and Long Run: Some Evidence from New Zealand," *American Journal of Agricultural Economics* 72 (1990): 160 - 171.

Rodrigues, P. M. M. and A. M. R. Taylor. "Alternative estimators and unit root tests for seasonal autoregressive processes*1." *Journal of Econometrics* 120(1) (2004): 35-73.

Schwert, W. "Tests for Unit Roots: A Monte Carlo Investigation," *Journal of Business and Economic Statistics* 7 (1989): 147 - 159.

Smith, R. J. and A. M. R. Taylor. "Additional critical values and asymptotic representations for seasonal unit root tests." *Journal of Econometrics* 85(2) (1998): 269-288.

Tomek, W. G. “Dependence in Commodity Prices: Comment,” *Journal of Futures Markets* 14 (1994): 103 - 109.

Zivot, E., Andrews, D.W.K., “Further Evidence on the Great Crash, the Oil Price Shock, and the Unit Root Hypothesis.” *Journal of Business and Economics Statistics* 10 (1992): 251-270.

Appendix I Alternate Tests

A. Dickey-Fuller (DF) unit root test in the absence of serial correlation

Dickey-Fuller tests for unit roots in the absence of serial correlation can be summarized as the following 4 cases.

Case 1: Regression model: $y_t = \rho y_{t-1} + \mu_t$; The true process: $y_t = y_{t-1} + \mu_t$, where where $\mu_t \sim$ i.i.d N(0, σ^2).

Case 2: Regression model: $y_t = \alpha + \rho y_{t-1} + \mu_t$; The true process: $y_t = y_{t-1} + \mu_t$, where where $\mu_t \sim$ i.i.d N(0, σ^2).

Case 3: Regression model: $y_t = \alpha + \rho y_{t-1} + \mu_t$; The true process: $y_t = \alpha + y_{t-1} + \mu_t$, $\alpha \neq 0$, $\mu_t \sim$ i.i.d N(0, σ^2). Then ($\hat{\rho}_T$ -ρ)/ $\hat{\sigma}_{\hat{\rho}_T}$ → N(0,1).

Case 4: Regression model: $y_t = \alpha + \rho y_{t-1} + \beta t + \mu_t$; The true process: $y_t = \alpha + y_{t-1} + \mu_t$, α any value, $\mu_t \sim$ i.i.d N(0, σ^2).

The distribution of rho test T($\hat{\rho}$ -ρ) and tau test ($\hat{\rho}$ -ρ)/ $\hat{\sigma}_{\hat{\rho}_T}$ for ρ=1 are described by DF and the critical values are available for the DF tests under case 1, case2 and case 4. The OLS F test under case 2 is that α =0, ρ=1 and is ρ=1, β=0 under case 4.

If the analyst has a specific knowledge about the process that generated the data, this should guide the choice of the specification. In the absence of such guidance, the principle is to fit a specification that is a plausible description of the data under both the null hypothesis and the alternative. Using the case 4 test (linear trend case) for a series with an obvious trend and the case 2 test (simple mean case) for series without a significant trend.

B. The Augmented Dickey-Fuller (ADF)

The null hypothesis of ADF is that there is a unit root against the alternative of stationary. The lagged difference variables are includes in order to account for serial correlation in the errors. We report the tau test results for case 2 and case 4.

Single mean case (case 2)

$$y_t = \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + \dots + \zeta_p \Delta y_{t-p} + \alpha + \rho y_{t-1} + \varepsilon_t \quad (1)$$

Under the null, the true value of ρ is 1 (and the true value of α is zero).

Linear trend case (case 4)

$$y_t = \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + \dots + \zeta_p \Delta y_{t-p} + \alpha + \beta t + \rho y_{t-1} + \varepsilon_t \quad (2)$$

The true process is the same specification as estimated regression with α of any value, ρ=1, and β=0. Notice that the maintained assumptions for both cases were that ε_t is i.i.d. with mean zero, variance σ^2, and finite fourth moment and that the roots of $1 - \zeta_1 Z - \zeta_2 Z - \dots - \zeta_p Z = 0$ are outside the unit circle. We choose the order of p as the minimum lag to generate a white noise residual and the last lag is statistically significant. The critical values are available in Hamilton, 1994.

C. Phillips-Perron (PP) unit root test

Phillips and Perron (1988) proposed the unit root test of the OLS regression model
$y_t = \rho y_{t-1} + \mu_t$ (3)
If equation (3) was a stationary autoregression with /ρ/ <1, the OLS estimate would not give a consistent estimate of ρ when u_t is serially correlated. However, if ρ=1, the rate T convergence of $\hat{\rho}_T$ ensure that $\hat{\rho}_T \rightarrow 1$ even when u_t is serially correlated. The unit root test statistics Rho and Tau are adjusted to get Z statistics to take account of the serially correlation.
The PP Z($\hat{\rho}$) test is

$$Z(\hat{\rho}) = T(\hat{\rho}-1) - \frac{1}{2}T^2\hat{\sigma}^2(\hat{\lambda}-\hat{\gamma}_0)/S^2 \quad (4)$$

where $S^2 = \frac{1}{T-k}\sum_{t=1}^{T}\hat{\mu}_t^2$, $\hat{\sigma}^2$ is the variance estimate of the OLS estimator $\hat{\rho}$, and $\hat{u}_t$ is the OLS residual. The asymptotic variance of $\frac{1}{T}\sum_{t=1}^{T}\hat{u}_t^2$ using truncation lag p.

$$\hat{\lambda} = \sum_{j=0}^{p} k_n(1-j/(p+1))\hat{\gamma}_j$$

where k_0=1, k_j=2 for j>0, and $\hat{\gamma}_j = \frac{1}{T}\sum_{t=j+1}^{T}\hat{u}_t\hat{u}_{t-j}$

The PP t-test statistic for $\hat{\rho}$, Z($t_{\hat{\rho}}$) is

$$Z(t_{\hat{\rho}}) = (\hat{\gamma}_0/\hat{\lambda})^{1/2}t_{\hat{\rho}} - \frac{1}{2}T\hat{\sigma}(\hat{\lambda}-\hat{\gamma}_0)/(S\hat{\lambda}^{1/2}) \quad (5)$$

We test the regression model with a constant or both a constant and a trend term in equation (3). The statistic Z($t_{\hat{\rho}}$) was reported. It has the same asymptotic distribution as the variable tabulated under the heading Case 2 or Case 4 in Table B.6 (Hamilton, 1994). PP test is a nonparametric adjustment of the simple DF test. The order of truncation lag is chosen as the same as in ADF specification.

D. Perron (1989, 1990) and Perron and Vogelsang (1992b) unit root test with structural break

The structural break models involve in testing for a unit root, allowing for the possibility of a change in the level and/or in the slope of the trend function. There are two types of models for the break: Additive Outlier (AO) Model and Innovational Outlier (IO) model. AO model assumes that the change takes effect instantaneously, and IO model assumes that the change affects the level of the series gradually. Since the data in our paper is monthly and the shocks always take several months, IO model is adopted in the analysis.

Perron (1989) structural break IO model with trending time series (Mean and Slope Case):

Under the null hypothesis of unit root:
Model A: $y_t = \beta + y_{t-1} + \psi(L)(\tau D2_t + \varepsilon_t)$,
Model B: $y_t = \beta_1 + y_{t-1} + \psi(L)((\beta_2 - \beta_1)D1_t + \varepsilon_t)$,
Model C: $y_t = \beta_1 + y_{t-1} + \psi(L)(\tau D2_t + (\beta_2 - \beta_1)D1 + \varepsilon_t)$,
Under the alternative hypothesis of stationarity, the model is
Model A: $y_t = \alpha_1 + \beta t + \phi(L)((\alpha_2 - \alpha_1)D1_t + \varepsilon_t)$,
Model B: $y_t = \alpha + \beta_1 t + \phi(L)((\beta_2 - \beta_1)D3_t + \varepsilon_t)$,
Model C: $y_t = \alpha_1 + \beta_1 t + \phi(L)((\alpha_2 - \alpha_1)D1_t + (\beta_2 - \beta_1)D1_t * t + \varepsilon_t)$,
where B is the break date, D1=1 when t>B, =0 otherwise; D2=1 when t=B+1, =0 otherwise; D3=t-B when t>B, =0 otherwise. Model A assumes that there is a change in the mean only. Model B assumes that the change happens in the slope of the trend function. Model C assumes that the change affects both the mean and the slope. Model C is estimated since it gives a more general specification when the series is with trend. By nesting the corresponding models under the null and alternative hypotheses, the following regression is constructed for model C:

$$y_t = \alpha + \gamma D1_t + \eta D2_t + \theta D1_t * t + \beta t + \rho y_{t-1} + \sum_{i=1}^{p} \zeta_i \Delta y_{t-i} + \varepsilon_t \quad (6)$$

Under the null hypothesis of a unit root for Model C: $\rho=1$, $\theta=0$, $\beta=0$ and η are expected to be significantly different from zero. Under the alternative hypothesis of a "trend stationary" process, we expect $\rho<1$, $\beta\neq0$, $\gamma\neq0$, $\theta\neq0$, and η close to zero. Regression is estimated by OLS. The test statistics reported is the tau statistic for testing $\rho=1$. The critical values of the tau statistics are listed in Perron (1989), Table VI.C.

Perron (1990), and Perron and Vogelsang (1992b) time series IO model with a changing mean (Mean Case):

Under the null hypothesis of unit root:
$y_t = y_{t-1} + \psi(L)(\tau D2_t + \varepsilon_t)$
Under the alternative hypothesis of stationarity, the model is
$y_t = \alpha_1 + \phi(L)((\alpha_2 - \alpha_1)D1_t + \varepsilon_t)$
Notice that there is no β under the null. By nesting the corresponding models under the null and alternative hypotheses, the following regression is constructed:

$$y_t = \alpha + \gamma D1_t + \eta D2_t + \rho y_{t-1} + \sum_{i=1}^{p} \zeta_i \Delta y_{t-i} + \varepsilon_t \quad (7)$$

The critical value is listed in Table3 and Table 4 of Perron (1990). Since the tests with more than one break in finite sample is less of power, in our paper, we assume that there is at most one change. The shift was assumed not a realization of the underlying data-generating mechanism of the various series, i.e. the shocks are exogenous. P is chosen as the minimum lag to generate a white noise residual and the last lag is with significant t value.

Appendix II Price Data

Soybean

Monthly average soybean farm price ($/bushel) received in Illinois for January 1960-December 2002.

Weekly Illinois regional (South Central Region) soybean cash price for September 4, 19975 to December 26, 2002.

Corn

Monthly average corn farm price ($/bushel) received in Illinois for January 1960-December 2002.

Weekly Illinois regional (South Central Region) corn cash price September 4, 19975 to December 26, 2002.

Barrows and Gilts

Monthly average barrow and gilts farm price ($/cwt) received in Illinois for January 1960-December 2002.

Milk Price

Monthly average milk farm price received in Illinois for January 1960-December 2002.

Consumer Price Index

Monthly Consumer Price Index U.S. city average, not seasonally Adjusted, January 1960-December 2002

Data Sources:
http://www.farmdoc.uiuc.edu/manage/pricehistory/price_history.html
http://www.farmdoc.uiuc.edu/marketing/cash/index.asp
http://data.bls.gov/servlet/SurveyOutputServlet

Figure 1. U.S. Monthly Soybean Price $/bushel, September 1960-August 2002, Illinois

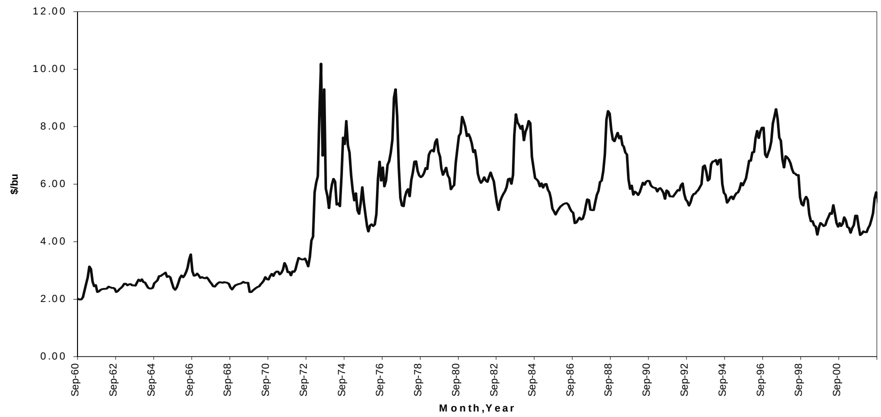

Figure 2. Monthly Corn Price ($/bushel), September 1960-August 2002, Illinois

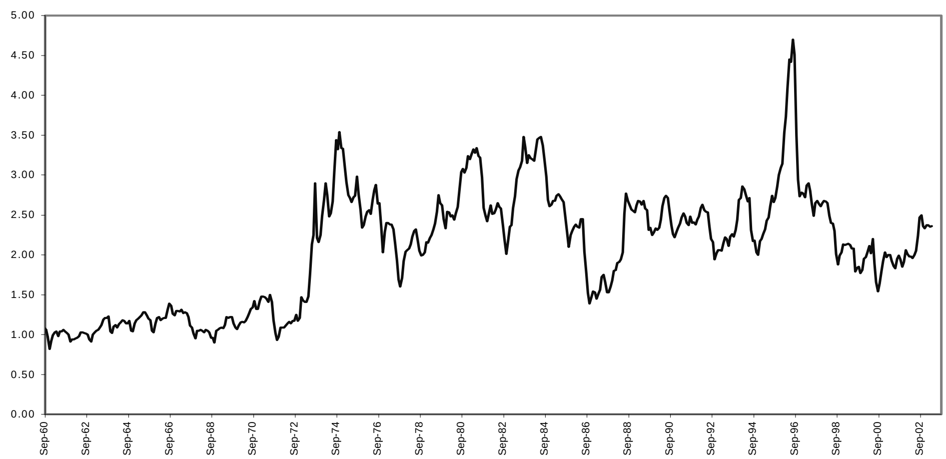

Figure 3 U.S. Monthly Barrows&Gilts Price ($/cwt) , January 1960-January 2002, Illinois

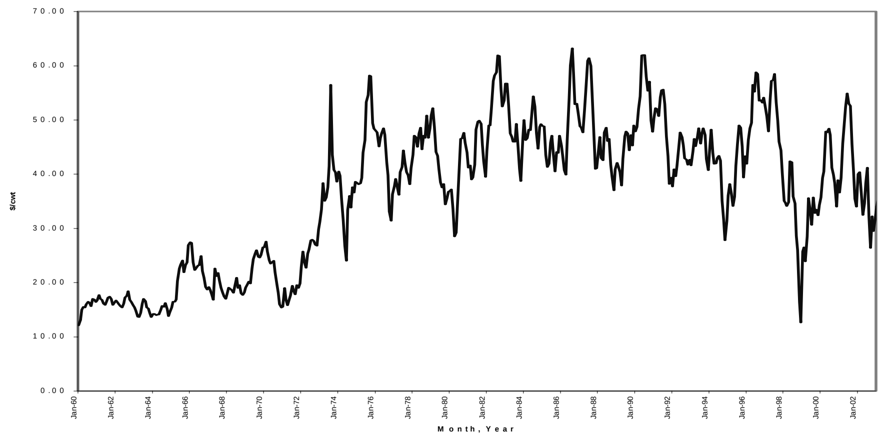

Figure 4 U.S. Monthly Milk Price ($/cwt), January 1960-January 2002, Illinois

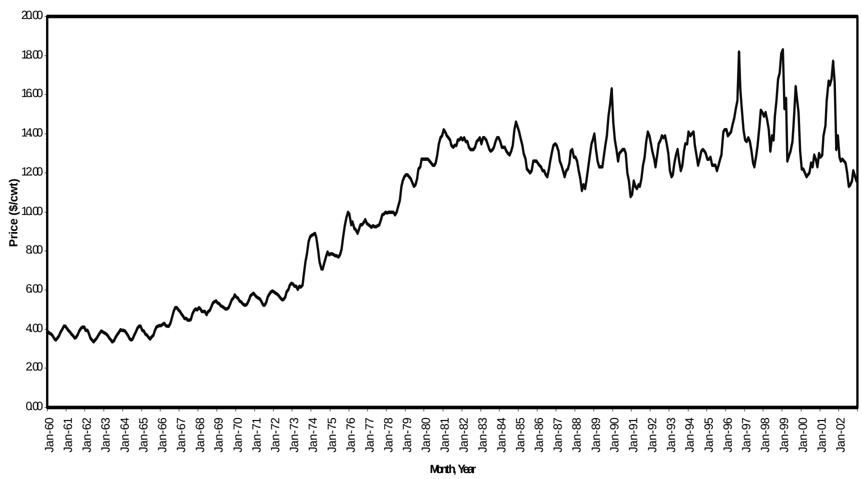

Figure 5 Monthly Consumer Price Index, January 1960-December 2002, U.S. City Average

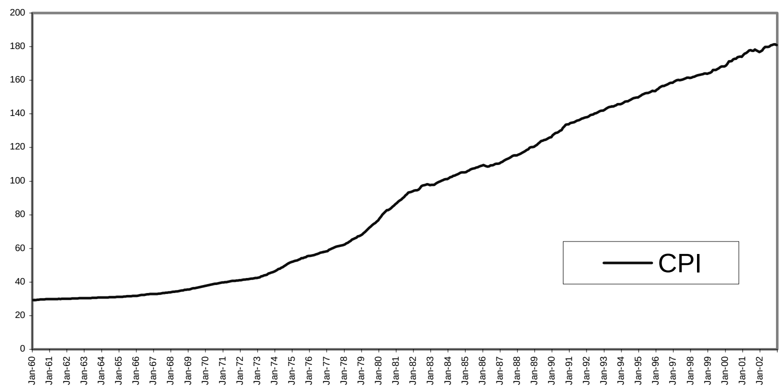

Table 1 Augmented Dickey-Fuller Unit Root Tests (Tau) for Full Sample, Monthly Data

Commodity/period	lags	Nominal	Deflated	Logarithm of nominal	logarithm of deflated
Soybean/1960.9-2002.8					
single mean case	1	-2.82*	-2.46	-2.54	-1.55
	2	-3.27**	-3.05**	-2.75*	-1.84
	3	-3.11**	-3.11**	-2.59*	-1.69
	4	-2.69*	-2.52	-2.26	-1.4
	5	-2.47	-2.02	-2.07	-1.24
	6	-2.56	-2.2	-2.08	-1.43
	7	-2.44	-2.24	-1.85	-1.29
	8	-2.31	-1.94	-1.81	-1.11
	9	-2.42	-1.78	-2.01	-1.09
	10	-2.39	-1.68	-2.02	-0.99
	11	-2.28	-1.63	-1.95	-1.05
	12	-2.33	-1.6	-2.09	-1.06
	the 10% critical value with T=500 is -2.57; 5% critical value is -2.87; 1% critical value is -3.44				
trend case	1	-3.2*	-3.84**	-2.78	-3.42**
	2	-3.87**	-4.64***	-3.17*	-3.82**
	3	-3.66**	-4.75***	-2.96	-3.58**
	4	-3.08	-3.94**	-2.51	-3.1
	5	-2.78	-3.25*	-2.25	-2.82
	6	-2.97	-3.43**	-2.4	-2.95
	7	-2.86	-3.37*	-2.14	-2.64
	8	-2.63	-3.02	-1.96	-2.49
	9	-2.72	-3	-2.09	-2.68
	10	-2.64	-2.94	-2.03	-2.64
	11	-2.51	-2.79	-2.02	-2.61
	12	-2.54	-2.82	-2.12	-2.77
	the 10% critical value with T=500 is -3.13; 5% critical value is -3.42; 1% critical value is -3.98				
Soybean/1960.9-2002.8					
trend case		-3.87** (2)	-3.25* (5)	-2.51 (4)	-3.10 (4)
Corn/1960.9-2002.8					
trend case		-3.36* (12)	-3.73** (12)	-3.11 (12)	-3.59** (12)
Barrow&Gilts/1960.1-2002.12					
trend case		-2.70 (15)	-3.20* (15)	-2.48 (15)	-3.30* (15)
Milk/1960.1-2002.12					
trend case		-0.19 (20)	-1.33 (20)	0.37 (20)	-1.12 (20)

The regression is $y_t = \alpha + \rho y_{t-1} + \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + ... + \zeta_{t-p} \Delta y_{t-p} + \varepsilon_t$ for simple mean case.

The regression is $y_t = \alpha + \beta t + \rho y_{t-1} + \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + ... + \zeta_{t-p} \Delta y_{t-p} + \varepsilon_t$ for trend case.

* A statistic significant at the 10% level; ** at the 5% level; *** at the 1% level.
Order of P: Choose the minimum lag to generate a white noise residual and the last lag is statistically significant.
C.V. source: Hamilton, 1994 Table B.6.

Table 2 PP Unit Root Tests (Tau) for Full Sample, Monthly Data

Commodity/period	Lags	Nominal	Deflated	Logarithm of nominal	logarithm of deflated
Soybean/1960.9-2002.8					
single mean case	1	-2.8*	-2.65*	-2.42	-1.39
	2	-2.93**	-2.81*	-2.49	-1.51
	3	-2.97**	-2.87*	-2.52	-1.56
	4	-2.95**	-2.84*	-2.51	-1.55
	5	-2.89**	-2.74*	-2.49	-1.51
	6	-2.86*	-2.7*	-2.47	-1.48
	7	-2.82*	-2.63*	-2.45	-1.45
	8	-2.79*	-2.58*	-2.43	-1.41
	9	-2.77*	-2.54	-2.41	-1.38
	10	-2.74*	-2.49	-2.39	-1.35
	11	-2.72*	-2.45	-2.37	-1.33
	12	-2.7*	-2.42	-2.37	-1.31
the 10% critical value with T=500 is -2.57; 5% critical value is -2.87; 1% critical value is -3.44					
trend case	1	-3.18*	-4.07***	-2.58	-3.17*
	2	-3.38*	-4.29***	-2.72	-3.32*
	3	-3.44**	-4.38***	-2.78	-3.38*
	4	-3.41*	-4.36***	-2.78	-3.38*
	5	-3.35*	-4.27***	-2.73	-3.34*
	6	-3.31*	-4.23***	-2.71	-3.31*
	7	-3.27*	-4.18***	-2.67	-3.28*
	8	-3.23*	-4.13***	-2.63	-3.24*
	9	-3.21*	-4.1***	-2.6	-3.21*
	10	-3.18*	-4.06***	-2.57	-3.18*
	11	-3.16*	-4.03***	-2.54	-3.16*
	12	-3.14*	-4.01***	-2.53	-3.15*
the 10% critical value with T=500 is -3.13; 5% critical value is -3.42; 1% critical value is -3.98					
Soybean/1960.9-2002.8					
trend case		-3.38* (2)	-4.27*** (5)	-2.78 (4)	-3.38* (4)
Corn/1960.9-2002.8					
trend case		-2.99 (12)	-3.07 (12)	-2.61 (12)	-3.03 (12)
Barrow & Gilts/1960.1-2002.12					
trend case		-3.39* (15)	-4.11*** (15)	-3.21* (15)	-4.06*** (15)
Milk/1960.1-2002.12					
trend case		-1.88 (20)	-1.91 (20)	-0.70 (20)	-1.82 (20)

* A statistic significant at the 10% level; ** at the 5% level; *** at the 1% level.
Order of P: the same as for ADF
Critical Value Source: Hamilton Table B.6.

Table 3 Split Sample ADF unit root tests, Monthly Data

Commodity/period	Nominal	Deflated	Logarithm of nominal	logarithm of deflated
Soybean/1960.9-1972.8				
trend	-3.94** (1)	-4.43*** (1)	-4.20*** (1)	-4.26*** (1)
1973.9-2002.8				
trend	-4.01*** (3)	-4.04** (3)	-3.84** (3)	-4.42*** (1)
Corn/1960.9-1972.8				
trend	-3.40* (12)	-2.81 (12)	-3.36* (12)	-2.85 (12)
1973.9-2002.8				
trend	-4.51*** (1)	-3.68** (10)	-4.39*** (1)	-4.06*** (1)
Barrow & Gilts/1960.1-1972.12				
trend	-3.74** (11)	-3.47** (11)	-3.71** (11)	-4.33*** (12)
1974.1-2002.12				
trend	-4.69*** (11)	-4.85*** (11)	-4.41*** (11)	-5.78*** (12)
Milk/1960.1-1972.12				
trend	-0.39 (12)	-2.57 (12)	-1.88 (12)	-2.78 (12)
1974.1-1980.12				
trend	-2.28 (11)	-4.42*** (11)	-3.53** (11)	-4.65*** (11)
1981.1-2002.12				
trend	-6.35*** (2)	-4.07*** (4)	-6.29*** (2)	-4.29*** (4)

* A statistic significant at the 10% level; ** at the 5% level; *** at the 1% level.

Table 4 Compare Monthly vs Weekly ADF unit root tests for Corn and Soybean, 1975.9-2002.8

part I

Commodity/period	**Case**	**Nominal**	**Deflated**	**Logarithm of nominal**	**logarithm of deflated**
Soybean, Monthly	trend	4.72*** (1)	-3.66** (3)	-4.48*** (1)	-4.18*** (1)
Weekly	trend	-4.23*** (8)	--	-3.61** (6)	--
Corn, Monthly	trend	-4.19*** (1)	-4.17*** (1)	-4.06*** (1)	-4.17*** (1)
Weekly	trend	-3.71** (7)	--	-3.37* (4)	--

part II

		nominal		**logarithm of the nominal**	
Commodity/type	**lags**	**weekly**	**monthly**	**weekly**	**monthly**
Soybean	1	-3.45***	-4.4***	-3.19**	-4.12***
Single mean	2	-3.69***	-4.1***	-3.37**	-3.92***
	3	-3.64***	-3.7***	-3.34**	-3.6***
	4	-3.89***	-3.66***	-3.54***	-3.5***
	5	-3.69***	-3.8***	-3.36**	-3.71***
	6	-3.57***	-3.59***	-3.28**	-3.57***
	7	-3.67***	-3.66***	-3.43**	-3.52***
	8	-3.84***	-3.51***	-3.55***	-3.33**
	9	-3.98***	-3.57***	-3.68***	-3.39**
	10	-4.24***	-3.56***	-3.95***	-3.42**
	11	-4.09***	-3.76***	-3.83***	-3.64**
	12	-4.2***	-3.51***	-3.9***	-3.42**
Trend	1	-3.82**	-4.72***	-3.61**	-4.48***
	2	-4.11***	-4.47***	-3.84**	-4.34***
	3	-4.09***	-4.09***	-3.83**	-4.06***
	4	-4.25***	-4.05***	-3.93**	-3.94**
	5	-4.02***	-4.23***	-3.72**	-4.2***
	6	-3.88**	-4.07***	-3.61**	-4.11***
	7	-4.07***	-4.15***	-3.88**	-4.07***
	8	-4.23***	-3.98**	-3.99***	-3.83**
	9	-4.28***	-3.9**	-4.01***	-3.71**
	10	-4.51***	-3.88**	-4.26***	-3.74**
	11	-4.31***	-4.23***	-4.11***	-4.11***
	12	-4.41***	-3.85**	-4.17***	-3.75**
Corn, single mean	1	-3.05**	-4.16***	-3.11**	-4.03***
	2	-2.96**	-3.86***	-3.22**	-3.68***
	3	-3.25**	-3.94***	-3.26**	-3.62***
	4	-3.35**	-3.51***	-3.35**	-3.35**
	5	-3.28**	-3.43**	-3.29**	-3.28**
	6	-3.44**	-3.12**	-3.37**	-3.11**

Table 4 Part II (Continued)

Commodity/type		lags	nominal weekly	monthly	logarithm of the nominal weekly	monthly
Corn	Simple Mean	7	-3.67***	-3.07**	-3.49***	-2.96**
		8	-3.65***	-3.06**	-3.43**	-2.82*
		9	-3.63***	-3.2**	-3.47***	-3**
		10	-3.62***	-3.28**	-3.5***	-3.09**
		11	-3.75***	-3.34**	-3.49***	-3.36**
		12	-3.91***	-3.59***	-3.51***	-3.6***
Corn	Trend	1	-3.1	-4.19***	-3.18*	-4.06***
		2	-3	-3.9**	-3.28*	-3.73**
		3	-3.31*	-3.97**	-3.32*	-3.65**
		4	-3.37*	-3.53**	-3.37*	-3.37*
		5	-3.27*	-3.45**	-3.28*	-3.3*
		6	-3.44**	-3.14*	-3.37*	-3.13
		7	-3.71**	-3.1	-3.53**	-2.98
		8	-3.7**	-3.07	-3.46**	-2.82
		9	-3.66**	-3.2*	-3.48**	-3
		10	-3.63**	-25.6	-3.5**	-3.09
		11	-3.74**	-3.36*	-3.45**	-3.38*
		12	-3.89**	-3.6**	-3.44**	-3.61**

A statistic significant at the 10% level; ** at the 5% level; *** at the 1% level.
For trend case:

10% CV with T large is -3.12; 5% CV is -3.41; 1% CV is -3.98
10% CV with T=250 is -3.13; 5% CV is -3.43; 1% CV is -3.99

For simple mean case: 10% CV with T large is -2.57; 5% CV is -2.86; 1% CV is -3.44
10% CV with T=250 is -2.57; 5% CV is -2.88; 1% CV is -3.46

Table 5 Full-Sample Unit-Root Tests With Structure Changes (IO model)

Series	Type of Change	B	$\hat{\gamma}$	$\hat{\beta}$	$\hat{\theta}$	$\hat{\eta}$	$\hat{\rho}$	Tau	λ	T
Soybean/1960.9-2002.8										
log(price)	Mean	1972.12	0.078***	--	--	-0.050	0.902***	-5.10***	0.3	504
log(real price)	Mean Slope	1972.12	0.109***	-0.00004	-0.0004***	-0.036	0.895***	-5.27***	0.3	504
Corn/1960.9-2002.8										
log(price)	Mean	1972.12	0.054***	--	--	-0.135**	0.926***	-4.98***	0.3	504
Barrow &Gilts/1960.1-2002.12										
log(price)	Mean	1972.12	0.090***	--	--	0.047	0.888***	-4.82***	0.3	516
Milk/1960.1-1980.12										
price	Mean Slope	1972.12	-0.910***	0.0024***	0.006***	-0.130	0.872***	-4.92***	0.4	252
real price	Mean Slope	1972.12	0.005**	0.00003***	-0.00002*	-0.004	0.861***	-5.36***	0.4	252
Log(price)	Mean Slope	1972.12	-0.033*	0.0004***	0.0003***	-0.026	0.896***	-4.69**	0.4	252
log(real price)	Mean Slope	1972.12	0.031**	0.0002***	-0.0001*	-0.024	0.867***	-5.16***	0.4	252
Milk/1974.1-2002.12										
price	Mean Slope	1980.12	0.951***	0.013***	-0.013***	0.410	0.835***	-5.39***	0.3	348
Log(price)	Mean Slope	1980.12	0.085***	0.001***	-0.001***	0.030	0.848***	-5.23***	0.3	348

IO model with a changing mean: $y_t = \alpha + \gamma D1_t + \eta D2_t + \rho y_{t-1} + \sum_{i=1}^{p} \zeta_i \Delta y_{t-i} + \varepsilon_t$

IO model with a change in mean and slope: $y_t = \alpha + \gamma D1_t + \beta t + \theta D1_t * t + \eta D2_t + \rho y_{t-1} + \sum_{i=1}^{p} \zeta_i \Delta y_{t-i} + \varepsilon_t$

D1=1 when t>B, =0 otherwise; D2=1 when t=B+1, =0 otherwise; TB=number of observations in first period; λ=TB/T=break ratio
The asymptotic critical values are from Perron (1990) Table 4 for model (I), and Perron (1989) Table VI.C for model (II), using the appropriate value of λ.