Cointegration Results of Farm Incomes and Production Costs in U.S. Agriculture

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Abstract

This study analyzes the dynamic relationships between farm incomes and production costs in the U.S. agricultural industry by applying the cointegration technique. The results provide evidence of long-run equilibrium relationships between cash marketings and production costs. However, the results do not show such relationships between total revenues, which include cash marketings and government payments, and production costs. Chief conclusions of this study are that if market forces alone were to guide farmers' decisions, one could expect long-run equilibrium relationships between the cash receipts and costs; however, government interventions seem to disrupt this equilibrium. The results also suggest that production costs can be forecasted using cash marketings which are found to be weakly exogenous. The Error Correction Model and Vector Autoregression Model are used to estimate and compare simulation performances of the cointegrated system of cash marketings and production costs.

togetherness. The purpose of this study is to analyze the dynamic relationships between the farm incomes and production costs in the U.S. agricultural industry by applying the cointegration technique. This technique allows us to estimate the error correction model for the cointegrated variables, which will be useful to examine the direction of Granger causality between farm incomes and production costs, and dynamic nature of long-run adjustments of these variables to past disequilibrium, and short-run effects of one variable on the other. Recent studies (Phillips and Durlauf (1986), Maddala (1992), and Phillips (1991)) have shown that if a set of variables are nonstationary and cointegrated, estimation of vector autoregression (VAR) models in levels will yield consistent parameter estimates. In view of this, we estimate and compare simulation performances of the cointegrated system under the error correction model and the VAR model.

In the United States, the farm policy programs began in 1933 after the Great Depression to provide income supports to farmers. Because of the additional subsidy income from government, there are two distinct types of incomes encountered in the U.S. agriculture. One is cash receipts from commodity marketings. The second is total revenues which include cash marketings plus the government subsidy payments. In this study, we also examine whether the additional income from the government alters the long-run relationships between the farm incomes and production costs.

This study proceeds as follows. Section II presents a brief review of the cointegration theory, and results of past studies that used the cointegration techniques. Section III describes briefly the U.S. farm policies which provide income supports to farmers. Section III discusses the data, methodology, and empirical results. The concluding section provides summary and policy implications of the empirical findings.

II. Cointegration Theory

In this section, we provide only a brief explanation of cointegration theory since there has been considerable focus on this topic in the recent literature.

Cointegration is a property associated with nonstationary time series data. If a time series is nonstationary and needs to be differenced d times to become stationary, then that series is said to be 'integrated of order d', denoted as I(d). Differencing is useful because using a nonstationary series in regression analyses may produce unreliable results since the usual distributional assumptions do not hold for nonstationary series (Hendry, 1986). Consider two series X_t and Y_t, both I(d); i.e., each is nonstationary, but differencing it d times induces stationarity. If a linear combination of X_t and Y_t is integrated of order b, I(b), and $b < d$, then X_t and Y_t are known to be 'cointegrated of order (d,d-b)', denoted as CI(d,d-b). In a special case where X_t and Y_t are of I(1), they will be cointegrated of order (1,1) if a linear combination of X_t and Y_t is stationary, i.e., I(0). This means that even if each series has a tendency to wander widely, their linear combination V_t is stationary. If V_t were not stationary then this would mean that X_t and Y_t would diverge from each other in the long run. Hence, cointegration of a pair of I(1) variables implies the existence of a long-run relationship between the two and vice-versa. Thus, if $X_t - \alpha Y_t = V_t$ is stationary, X_t and Y_t are said to be cointegrated of order (1,1) with α known as the vector of cointegrating parameters. The regression $X_t = \alpha Y_t + V_t$ is considered as the cointegrating or equilibrium regression. More specifically, $X_t = \alpha Y_t$ is referred to as the long-run or equilibrium relationship, and V_t measures the extent to which the system X_t and Y_t is out of equilibrium (see Granger, 1986).

Granger (1983) and Engle and Granger (1987) have postulated that if X_t and Y_t are both I(1) and cointegrated, an error correction model (ECM) of the joint process of X_t and Y_t can be represented as:[4]

$$\Delta X_t = -\rho_1(X_{t-1} - \alpha Y_{t-1}) + \text{lagged}(\Delta X_t, \Delta Y_t) + \text{residual} \quad (1a)$$

$$\Delta Y_t = -\rho_2(X_{t-1} - \alpha Y_{t-1}) + \text{lagged}(\Delta X_t, \Delta Y_t) + \text{residual} \quad (1b)$$

where the symbol Δ refers to change, i.e., first order difference. Coefficients ρ_1 and ρ_2 are such that $|\rho_1| + |\rho_2| \neq 0$ and at least one of the coefficients is nonzero. Residuals are a pair of independent, zero-mean white-noise series with finite variances. The term, X_{t-1}-αY_{t-1}, is called 'spread' or equilibrium error and measures the extent to which X and Y are out of equilibrium in t-1. In the ECM, the magnitude and sign of the previous equilibrium error influences the size and direction of changes in X_t and Y_t. Thus, the changes in X_t and Y_t are due to the immediate, short-run effects from the changes in X_t and Y_t and to last period's spread or error (Hakkio and Rush). Since the term X_{t-1} - αY_{t-1} is an argument in at least one of the error correction equations, knowledge of X_{t-1} and Y_{t-1} must improve the forecastability of X_t or Y_t or both. The ECM allows the long-run deviations to affect the short-run behavior of X_t and Y_t.

The original application of cointegration theory by Engle and Granger (1987) found evidence of a long-term relationship between U.S. consumption on nondurables and real per capita income but none between monthly wages and prices. Nachane, *et al.* (1988) found a long-run relationship between per capita energy consumption and income for 16 out of 25 countries tested for the period 1950-51 to 1984-85. Jenkinson (1986) tested the neoclassical theory of labor demand using U. K. data and found no support for long-run equilibrium relationship.

Monetary economists have found cointegration theory to be a useful tool in determining the appropriateness of using a particular variable as a target of monetary policy. Hence, studies which used the cointegration technique to establish long-run relationships between money supply and income (Engle and Granger, 1987; Cesar, *et al.* 1990; MacDonald, 1990), between short and long-term interest rates (Engle and Granger, 1987; Cesar, *et al.* 1990, Bonham, 1991), between interest rates and inflation (Atkins, 1989; MacDonald and Murphy, 1989) and between consumer price index and a commodity price index (Marquis and Cunningham, 1990) found mixed results.

Taylor (1992) found evidence of long-run purchasing power parity relationship between dollar-sterling exchange rate in the 1920s. Cointegration theory is used to test the efficient market hypothesis. Hakkio and Rush (1989) concluded that results of U.K. and German foreign exchange markets are inconsistent with market efficiency. Another application of cointegration theory is to study price movements of a commodity in different regions. Bessler and Covey (1991) examined the behavior of cattle prices in several regions in the United States and found evidence of cointegration among these prices. Bessler and Fuller (1991) concluded that wheat prices in the United States exhibit long-run equilibrium relationships. Tegene and Kuchler (1991) found that farmland prices and rents in five Corn Belt States in the United States to be cointegrated.

III. A Brief Review of U.S. Agricultural Policies

A portion of farm incomes in the United States comes from government payments. Since U.S. agriculture is a competitive industry, one would expect the farm incomes and production costs to be cointegrated; however, the additional incomes from the government may disrupt this relationship. Considering the role the government payments play in explaining the long-term relatedness of farm incomes and costs, it is worth reviewing the history of the U.S. farm policies and their effects on farm incomes.[5]

From 1987 to 1910, American agriculture experienced a sustained recovery and favorable economic milieu as farm prices rose steadily relative to nonfarm prices. These good years were followed by the Golden Age of American Agriculture from 1910 to 1914 as farm product prices were high and terms of trade (i.e., farm prices vs nonfarm prices) were strongly in favor of farmers. In these favorable climates, agricultural economic variables such as prices, supply, demand, costs, and incomes were primarily determined by market forces.

But with cessation of World War I and reduced demand for U.S. commodity exports, farm prices plummeted. This decline was further exacerbated by the farm depression which began in 1920, and farm prices tumbled again. The bleak future for American farmers got worse as the Great Depression (1929 - 1933) unfolded. During the Great Depression, net farm incomes declined by over 50 percent, and farmers were deeply hurt.

As the farm depression deepened, farmers turned to the government for price and income supports. The government reacted with the first Agricultural Adjustment Act in 1933. This and the ensuing acts and farm legislations since then defined the national agricultural policies' programs and regulations aimed at providing income supports to farmers. In some years, to control over-production, the government required farmers to take a certain portion of land out of production, but paid the farmers to compensate the revenue loss. Thus, farmers might not have incurred loss in their total revenue, but their production expenses declined. Government payments, though varied over the years, comprised a significant portion of farmers' incomes. For instance, in 1939 farmers received $763 million dollars from the government, which is about 10 percent of the income from marketings. As recently as 1987, farmers received about $12 billion dollars from the government, which is about 12 percent of the income from marketings. Given the magnitude of the government payments, it is worth studying whether these supplemental incomes have altered the long-run relationship between the farm revenues and production costs.

IV. Empirical Results

In this section, we describe the data used for the analysis, discuss the procedures involved in cointegration tests and VAR estimation, and present the empirical results.

The empirical analysis employs annual data on production expenses for all agricultural commodities (C), cash receipts from marketings of all commodities (M), and total revenues (T) which include income from marketings and government payments. The data for these variables were obtained from the USDA's agricultural statistics publications. Data for M and C cover the period 1910-88. Since the U.S. government commodity programs started only after 1933, data for T cover the period 1933-88.

The analysis is carried out to determine the existence of the long-run relationship between M and C using the data for the longer period. Then for the shorter period, cointegration between M and C and between T and C is tested. Recalling that the only difference between M and T is the government payments, a difference in the test results between the two tests could be attributed to the government payments.

The test procedures applied are as follows. We first tested the hypothesis that the data series are I(1), i.e., nonstationary. The M and C series are tested for the 1910-88 period and the M, C and T series for the 1933-88 period. All three series in levels are tested to find out if they are I(1), and these tests are followed by the tests to see if the series in the first differences are I(0), i.e., stationary. For this purpose, the augmented Dickey-Fuller (ADF) unit root tests outlined in Fuller (1976) are utilized. The augmentation allows for the possibility that the series follow a higher order auto-regressive process. The model estimated for testing the unit root is

$$\Delta X_t = c_0 + b_0 X_{t-1} + \sum_{i=1}^{m} b_i (\Delta X_{t-i}) + e_t \qquad (2)$$

where the lag length m is large enough to ensure that e_t is white-noise. The null hypothesis is that the series contain a unit root and are therefore nonstationary. In order to conclude that the data series used for the analysis are I(1), we require a nonsignificant ADF for the original levels and a significant ADF for the first differences, implying that the series are nonstationary in the levels but differencing produces stationarity. The ADF test is taken from the t-value of b_0 which in this case is not distributed as the standard t. A significant ADF is one which is negative and significantly different from 0.

The test statistics are reported in Table 1. The t-statistics indicate that the null hypothesis of nonstationarity of M, C, and T series cannot be rejected for both time periods. The ADF values for the original levels are all positive and insignificant. The tests on the first differences show that the ADF values are negative and significant in all cases. Thus the test results confirm that the series are I(1) and become stationary after first differencing.

Since the null hypothesis that the series are I(1) is not rejected, we can proceed to examine the cointegration relationship. The cointegrating regressions are run and the residuals from the regressions are tested to see if they are I(0). Hendry (1986) indicated that the direction of regression (X_t on Y_t or Y_t on X_t) in the equilibrium equation should not affect the outcome of the test if the variables are cointegrated. For this analysis, we ran regression in both directions. To check for cointegration, residuals from the estimated equilibrium equation are tested for nonstationarity by using equation (2); cointegration requires that residuals are stationary. The results are reported in Table 2.

For the period 1910-88, the tests show evidence of cointegration between cash marketings (M) and production costs (C). The results for the shorter period also support the notion of cointegration between M and C. However, total revenues (T) and C do not show any evidence of being cointegrated. These results indicate that exclusive of government payments, U.S. farmers' cash incomes from marketings and production costs exhibit a long-run equilibrium relationship. This means that if market forces alone were to guide farmers' decisions, a long-run relationship could be expected between cash marketings and costs. Thus, the results support the assertion of Granger (1986) that sales revenues and production costs exhibit long-run equilibrium relationships. These results are also consistent with the marginal productivity theory and competitive market assumptions that in the long-run total input payments equal sales revenues.

However, government intervention in the form of income supports and supply control programs seems to alter this equilibrium relationship. This is because the additional income from government is not in response to the cost of production increase; rather, it is paid in the tradition of agricultural policies which make the farmers dependent on government for supplemental income and because of the pressure from the farm lobbying group. Since, the government income support programs require farmers to set aside a certain amount of land from production,[6] farmers use less inputs and incur lower cost of production, though the revenue loss due to the set aside of land is compensated with the government payments.[7] Therefore, farmers may not incur loss in revenue but their production cost declines. Consequently, government programs prevent the total revenue and production expenses from moving together in the long run.

Since evidence of cointegration between M and C exists irrespective of the time period, an error correction model (ECM) of the form given in equations (1) can be estimated. The ECM provides an alternative test of existence of the equilibrium relationship imposed by the economic theory, and this test is on occasions more powerful than cointegration tests (Jenkinson, 1986). As presented in equations (1), ECM consists of the same number of equations as the variables in the system. In each equation, the dependent variable is change in one of the variables, the regressors are lagged changes in each variable in the system and lagged value of the spread or equilibrium error from the cointegration regression. Thus, these models exhibit the data generating mechanism for M or C given the previous period's equilibrium error and lagged changes of the variables in the system.

Following the approach of Hendry (1986) and Engle and Granger (1987), a parsimonious representation of the data generating process was estimated. The regression results are reported in Table 3 for the 1910-88 period and in Table 4 for the 1933-88 period. The results show that in both periods, the lagged equilibrium error is significant in the cost equations, but not in the cash marketings equations. This implies that the dynamics of the system involve adjustments only in the production costs to restore equilibrium. More specifically, any shock to cash marketings that generates an equilibrium error would cause adjustments in the production costs only. Furthermore, as elucidated by Granger (1986), if two variables are cointegrated, there will be at least one direction by which one variable in the system can 'Granger-cause,' and thus, help forecast the other variable. The results show that causality runs from the cash marketings to production costs, and thus, the cash marketings can be used to forecast the production costs. Lagged changes in M and C in the cost equations are also significant, indicating that the dynamics of production costs do respond to the short-run effects of lagged changes in M and C.

In contrast, the lagged equilibrium error is not significant in the cash marketing equations in both periods, implying that M do not adjust to the equilibrium error in the long run. Thus, the causality does not run from the production costs to cash marketings. This suggests that M can be considered as a weakly exogenous variable (Engle and Granger, 1987), and thus, the cash marketings can not be forecasted using production costs. This is consistent with the behavior of the competitive market in that the output prices are exogenous to farmers, and cash marketings are also predetermined for a given amount of output sales. Consequently, farmers try to minimize production costs by employing optimal input combinations and extract maximum profits from the available land. Thus, the Granger Causality from the cash marketings to production costs, but not vice versa, is consistent with the underpinnings of the competitive market conditions in the U.S. agriculture.

Recent studies by Phillips and Durlauf (1986), Sims et al. (1990), and Phillips (1991) have shown that VAR models provide consistent parameter estimates for a system of endogenous variables that are nonstationary and cointegrated. Since M and C are nonstationary and cointegrated, estimation of a VAR model for M and C in levels are appropriate. In what follows next, we describe the estimation of VAR model for both periods and compare its performance with the ECM using historical simulations.

The relationship between M and C can be represented by a VAR as

$$[I - A(L)]Z(t) = \varepsilon(t)$$

where $Z(t) = [M(t), C(t)]$, I a is 2x2 identity matrix, A(L) is a matrix polynomials in the lag operator L, and $\varepsilon(t)$ is a 2x1 innovation vector.

The first step in applying VAR is to estimate the lag length of the variables. A likelihood ratio test suggested by Sims(1980) is used for this purpose. The test statistic

$$V = (T - k)(\ln \det\Sigma(n\text{-}1) - \ln \det\Sigma(n))$$

is asymptotically distributed as $\chi^2(q)$ under the null hypothesis that $A_n = 0$, where $\Sigma(n)$ is the sample covariance matrix for a lag length of n, T is the sample size, and k is the number of coefficients per equation in the unrestricted model ($k = 2n + 1$), and q is the number of restrictions tested ($q = 4$). The test results indicated a lag length of eleven for the period 1910-1988 since the computed value of χ^2 is 14.57 with 0.006 significance level. For the period 1933-1988, the results showed a lag length of ten with χ^2 value of 12.87 at 0.012 significance level. Based on these lag lengths unrestricted VAR models of M and C were estimated for both periods.

Using the estimates of VAR and ECM, historical simulations were generated. The performances of VAR and ECM are evaluated by comparing the Root Mean Square

Percent Errors (RMSPE), which are presented in Table 5. The results indicate that RMSPE for both variables in both time periods are comparable under the VAR and ECM models, though there are minor differences. Based on these results, we conclude that VAR models perform very similarly to ECM models. This similarity is expected since VAR models of nonstationary and cointegrated variables yield consistent parameter estimates.

It is interesting to observe that RMSPE are higher for the period 1910-1988 than for the period 1933-1988. This is because during the farm depression, which began in 1920 and continued through the great depression (1929-1933), cash marketings and production expenses are very volatile due to higher price variabilities. Consequently, the simulated values did not track the actual values very closely in this period.

V. Summary and Policy Implications

The economic theory postulates that in a competitive industry the sales revenues and input costs will be equal in the long run. Consequently, as noted by Granger (1986), one would expect the revenues and costs to move together in the long run. The purpose of this study was to test for the existence of a long-run equilibrium relationship between the farm incomes and production costs in U.S. agriculture. This test was conducted by using cointegration techniques for production costs, cash receipts from marketings, and total revenues which also include government payments. Results provide evidence of cointegration between the cash marketings and costs, but not between total revenues and costs. These results suggest that if market forces alone were to guide farmers' decisions, one could expect long-run equilibrium relationships between the cash receipts and costs. Government interventions, however, seem to disrupt this equilibrium. In addition, the results suggest that the production costs can be forecasted using the cash marketings, which are weakly exogenous.

The government payments are subsidy incomes paid to farmers largely because of the pressure put on the government by the farm lobbying group, and not guided by market mechanisms. If market mechanisms were to guide government's decisions to subsidize farmers, one would expect the total revenues and production costs to be cointegrated. But, on the contrary, they are not cointegrated.

The implication of the results will be useful to farm policy decision makers. There are three forces which may force the government to cut down the farm program budgets. First, the U.S. government feels the urgent need to reduce the unprecedented budget deficit. Because of the high visibility of the farm subsidy programs, the government may be forced to turn to farm program expenditures for possible budget reductions. Second, there is a strong feeling among the Urban communities that farmers receive more than their due share of subsidies. Consequently, Urban legislators, reflecting the feeling of their communities, often raise their voices to trim the farm program expenditures. Third, the GATT (General Agreement on Tariff and Trade) negotiations require elimination of government farm subsidies which are often cited as the cause for the over- production and trade disputes. In light of these developments, farm programs will be closely scrutinized for possible reduction of expenditures on some commodity programs and total elimination of some other programs. Consequently, farm policy makers need to carefully examine what programs should receive priorities for government assistance. One possible guideline for such decision making would be to make sure that the total revenues (inclusive of government payments) and production costs reflect the behavior of a competitive industry. Government supports based on this guideline may avoid excess subsidies to certain farm programs and lead to need-based government assistance.

Footnotes

1. In the original derivation of the MPTD, theorists required the production function to be homogeneous of degree one. However, as shown in Henderson and Quandt (1981), the MPTD can be derived without succumbing to homogeneous production function of degree one, rather simply using the free entry and exit assumption of the competitive industry.

2. Other examples of long-run equilibrium relationships among economic variables as elucidated by Granger (1986) include: interest rates on assets of different maturities; incomes and expenditures of local governments; and prices of a commodity in different regions of the country.

3. The agricultural industry is historically cited in numerous text books as the standard example of a competitive industry. This fact has been highlighted by Tomek and Robinson (1990), who indicate that agriculture in the United States is a highly competitive industry, and farmers are price takers both in the output and input markets.

4. This representation is termed as Granger Representation Theorem in the literature.

5. An elaborate discussion of the history of U.S. agriculture and various farm programs can be found in Cochrane (1979) and Paarlberg (1980).

6. The land set aside from (i.e., taken out of) production in some years is as high as 20 percent of the total acreage used for growing crops (see Green and Baumes, 1989).

7. Some may argue that farmers may use the program acreage (acreage allowed to plant after the set aside) intensively by applying more inputs and, thus, the cost of production may not decrease much. However, U.S. agriculture is very intensive even without the farm programs. Consequently, further intensive production is limited on the planted acreage, and thus, the production expenses are likely to decrease.

References

Atkins, F.J. (1989). Co-integration, Error Correction and the Fisher Effect, *Applied Economics*, **21**, 1611-20.

Bonham, C. S., (1991). Correct Cointegration Tests of the Long-run Relationship Between Nominal Interest Rate and Inflation, *Applied Economics*, **23**, 1487-1492.

Bessler D. A., and T. Covey (1991). Cointegration: Some Results on U.S. Cattle Prices, *Journal of Futures Markets*, **11**, 461-474.

Bessler D. A., and S. W. Fuller (1991). Cointegration Among Wheat Markets. Department of Ag. Economics, Texas A&M University. College Station, Texas.

Cesar, H., J. Haan, and J. Jacobs (1990). Monetary Targeting in the Netherlands: an Application of Co-integration Tests, *Applied Economics*, **22**, 1537-48.

Cochrane, Willard W. (1979). *The Development of American Agriculture: A Historical Analysis*. Minneapolis: University of Minnesota Press.

Durlauf, S. N., and P. C. B. Phillips (1988). Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root, *Econometrica*, **49**, 1057-1072.

Engle, Robert F. and C.W.J. Granger (1987). Co-Integration and Error Correction: Representation, Estimation and Testing, *Econometrica*, **55**, 251-76.

Fuller, W.A. (1976). *Introduction to Statistical Time Series*. John Wiley, New York, p. 373.

Granger, C.W.J. (1983). Cointegrated Variables and Error-Correcting Models, University of San Diego, Discussion Paper 1983.

Granger, C.W.J. (1986). Developments in the Study of Cointegrated Economic Variables, *Oxford Bulletin of Economics and Statistics*, **48**, 213-28.

Green, R. and H. Baumes (1989). Supply Control Programs for Agriculture in *Agricultural-Food Policy Review: U.S. Agricultural Policies in a Changing World*, U.S. Department of Agriculture, Washington D.C.

Hakkio, Craig S. and Mark Rush (1989). Market Efficiency and Cointegration: an Application to the Sterling and Deutschmark Exchange Markets, *Journal of International Money and Finance*, **8**, 75-88.

Hall, S.G. (1986). An Application of the Granger and Engle Two-Step Estimation Procedure to United Kingdom Aggregate Wage Data, *Oxford Bulletin of Economics and Statistics*, **48**, 229-39.

Henderson, J. M., and R. E. Quandt (1981). *Microeconomic Theory: A Mathematical Approach*. New York: McGraw-Hill.

Hendry, David F. (1986). Econometric Modelling of Cointegrated Variables: An Overview, *Oxford Bulletin of Economics and Statistics*, **48**, 201-12.

Jenkinson, T.F. (1986). Testing of Neo-classical Theories of Labor Demand: an Application of Cointegration Techniques, *Oxford Bulletin of Economics and Statistics*, **48**, 241-51.

MacDonald, G.A. (1990). Testing for Stationarity and Co-integration: an Application to Saudi Arabian Monetary Data, *Applied Economics*, **22**, 1577-90.

MacDonald, R. and P.D. Murphy (1989). Testing for the Lon-run Relationship between Nominal Interest Rates and Inflation Using Cointegration Techniques, *Applied Economics*, **21**, 439-47.

Marquis, Milton H. and Steven R. Cunningham (1990). Is There a Role for Commodity Prices in the Design of Monetary Policy? Some Empirical Evidence, *Southern Economic Journal*, **57**, 394-412.

Nachane, Dilip M.; Ramesh M. Nadkarni; and Ajit V. Karnik (1988). Cointegration and Causality Testing of the Energy-GDP Relationship: a Cross-Country Study, *Applied Economics*, **20**, 1511-31.

Maddala, G. S., 2d ed. (1992). *Introduction to Econometrics*. New York: Macmillan Pubilishing Company.

Paarlberg, Don (1980). *Farm and Food Policy*. pp. 14-58. Lincoln: University of Nebraska Press.

Phillips, P. C. B. (1991). Optimal Inference in Cointegrated System, *Econometrica*, **59**, 283-306.

Phillips P. C. B., and S. Durlauf (1986). Multiple Time Series Regression with Integrated Process, *Review of Economic Studies*, **53**, 473-495.

Sims, C. (1980). Macroeconomics and Reality, *Econometrica*, **48**,, 1-49.

Sims, C., J. H. Stock, and M. W. Watson (1990). Inference in Linear Time Series Models with Some Unit Roots, *Econometrica*, **58**, 113-144.

Taylor, Mark P. (1992). Dollar-Sterling exchange rate in the 1920s: Purchasing Power parity and the Norman Conquest of $4.86, *Applied Economics*, **24**, 803-811.

Tegene, A. and F. Kuchler (1991). An Error Correcting Model of Farmland Prices, *Applied Economics*, **23**, 1741-1747.

Tomek, W. G., and K. L. Robinson. 2d ed. (1990). *Agricultural Product Prices*. Ithaca, New York: Cornel University Press.

U.S. Department of Agriculture. *Agricultural Statistics*. Washington, D.C., various issues.

Table 1. Tests for Stationarity of Cash Marketings (M), Production Costs (C), and Total Revenue (T).

Variables	Levels ADF	First Difference ADF
1910-88		
Cash Marketings(M)	1.96	-5.45
Production Expenses(C)	1.03	-4.15
1933-88		
Cash Marketings(M)	1.00	-4.86
Production Expenses(C)	0.38	-3.65
Total Revenue(T)	1.59	-4.68

Note: Critical values are from Fuller (1976, Table 8.5.2, p. 373): -2.93 (5 %) and -2.60 (10 %).

Table 2. Cointegrating Regressions and Tests of Cointegration of Cash Marketings (M), Total Revenue (T), and Production Expenses (C).

Model : $X_t = a_0 + a_1 Y_t + V_t$

Variables X	Variables Y	a_0	a_1	R^2	ADF
1910-88					
M	C	4788.41	1.0368	0.99	-3.28
C	M	-4212.46	0.9548	0.99	-3.34
1933-88					
M	C	6580.40	1.0182	0.99	-3.13
C	M	-5860.92	0.9713	0.99	-3.13
T	C	6454.62	1.0706	0.99	-2.83
C	T	-5273.61	0.9210	0.99	-2.89

Note: Critical values are from Engle and Granger (1987, Tables II and III): -3.17 (5 %) and -2.91 (10 %)

Table 3. Error Correction Models for Cash Marketings (M) and Production Costs (C), 1910-88

Independent Variables	Dependent Variable	
	M	C
V(-1)	-0.0481(-0.43)	-0.1783(-1.90)
ΔM(-1)		-0.2147(-1.60)
ΔM(-5)		0.4052(2.73)
ΔC(-1)	0.9673(5.79)	1.1109(6.56)
ΔC(-2)	-0.5856(-3.57)	-0.5493(-3.84)
ΔC(-3)		0.3399(2.38)
ΔC(-5)		-0.3749(-1.67)
Intercept	1343.58(2.53)	563.84(1.51)
D.W.	1.93	1.83
R^2	0.33	0.63

Note: Figures in parentheses are t-values.

Table 4. Error Correction Models for Cash Marketings (M) and Production Costs (C), 1933-88

Independent Variables	Dependent Variable	
	M	C
V(-1)	-0.1140(-0.77)	-0.2705(-2.45)
ΔM(-1)		-0.3980(-2.54)
ΔM(-5)		0.2086(2.18)
ΔC(-1)	0.9470(4.84)	1.2265(5.90)
ΔC(-2)	-0.6346(-3.29)	-0.3722(-2.72)
Intercept	2142.83(2.78)	921.67(1.62)
D.W.	1.96	1.77
R^2	0.34	0.59

Note: Figures in parentheses are t-values.

Table 5. Comparisons of Root Mean Square Percent Errors from VAR and ECM Models.

	VAR	ECM
1910-1988		
Cash Marketings(M)	1.429	1.368
Production Expenses(C)	0.919	1.208
1933-1988		
Cash Marketings(M)	0.409	0.470
Production Expenses(C)	0.354	0.385