Explaining Farmland Price Dynamics

Madhab R. Khoju and Bruce L. Ahrendsen

Proceedings of a Seminar sponsored by
North Central Regional Project NC-207
“Regulatory, Efficiency and Management Issues Affecting Rural Financial Markets”
Federal Reserve Bank of Chicago
Chicago, Illinois
October 4-5, 1993

Department of Agricultural, Resource and Managerial Economics
College of Agricultural and Life Sciences
Cornell University, Ithaca, New York 14853

December 1993

EXPLAINING FARMLAND PRICE DYNAMICS

Madhab R. Khoju and *Bruce L. Ahrendsen*[1]

Abstract

The relationship between farmland price and cash rent is examined in this paper. Cointegration and error correction models are applied to Arkansas farmland prices and cash rents for the period 1922 through 1992. Results show that Arkansas farmland prices and cash rents are cointegrated of order one. Thus a long-run relationship between farmland price and cash rent and the present value model for asset valuation are supported. The error correction model is used to better explain the short-run adjustments in farmland prices. Cash rents are found to cause farmland prices. Although the cointegration results are consistent with some studies, the results are inconsistent with other studies. The particular reasons for the different results among studies should be identified in the future.

The average per acre farmland price in the United States increased at an average annual rate of 13.5 percent from 1971 to 1981. However, by 1987, farmland prices fell by more than a third from their 1981 peak. In inflation adjusted terms, the price of farmland declined by 55.9 percent from 1981 to 1987. Since farmland constitutes the largest share of assets for the majority of farmers, farmers' net worth and, therefore, their financial security are sensitive to farmland price dynamics. Moreover, since farmland is often mortgaged as collateral to secure loans, the safety of these loans and, therefore, the financial condition of the lending agencies are also dependent on farmland price dynamics. Accordingly, the appreciation of farmland prices in the 1970's contributed to the financial prosperity of both farmers and lenders while the depreciation of the 1980's had the opposite effect. As a result, a better understanding of farmland price dynamics has been a topic of widespread research interest. This paper investigates the appropriateness of the cointegration and error correction models in explaining Arkansas farmland price dynamics.

A brief discussion on the time series properties of farmland prices from previous studies is given in the next section. Then cointegration and error correction models for farmland prices and cash rents are presented. The model presentations are followed by a description of the data. Next, the results from the estimated cointegration and error correction models are presented and analyzed. Finally, concluding comments are offered.

Time Series Properties of Farmland Prices

Different explanations for the rise and fall of farmland prices include changes in risk (Barry), changes in nonfarmland returns to land (Robison, Lins, and Venkataraman), changes in net rents (Alston; Burt), capital gains (Melicher; Klinefelter; Castle and Hoch), inflation rates and changes in real returns on alternative uses of capital (Just and Miranowski); credit market constraints and imperfections (Shalit and Schmitz), interaction of inflation and tax laws (Feldstein) and overreaction to changes in net rents (Featherstone and Baker). The basic framework for the majority of these studies is based on the present value model of asset prices.

---

[1] The authors are research associate and assistant professor of agricultural economics at the University of Arkansas, respectively. The authors are associates of The Center for Farm and Rural Business Finance which is jointly sponsored by the University of Illinois and the University of Arkansas. The helpful comments of Bruce L. Dixon are greatly acknowledged. This material is based upon work supported by the Cooperative State Research Service, U.S. Department of Agriculture, under Agreement No. 92-34275-8226.

Following the present value model, farmland price equals the discounted value of the future stream of net rents from the land (Burt; Featherstone and Baker; Alston). Moreover, for a constant discount rate, there is a long-run relationship between the equilibrium farmland price and net rent (Burt; Tegene and Kuchler). A change in land price, therefore, should arise from a change in expected net rents to land. Net rent expectations, however, are influenced by many factors like input and output prices, mortgage rates, discount rates, supply of land, technological change, etc. Since these factors are difficult to forecast, rent formation expectations of the buyers and sellers of land result in short run dynamic adjustments to land valuation. As information about future rents becomes available, rent expectations are updated which in turn affect the farmland value. Burt used a second-order rational distributed lag on net crop-share rents received by landlords to capture the dynamic movement of prices.

Engle and Granger used the cointegration techniques to study the long-run relationship between consumption expenditures and income, wages and prices, and short and long term interest rates. They also used the error correction representation to represent the short-run dynamics. Accordingly, the cointegration technique also seems appropriate to study long-run relationships between farmland prices and rents while the error correction representation is appropriate to study the short-run dynamics of farmland prices. Cointegration, however, requires that each of the two series must be integrated of the same order and their linear combination yield a stationary series. Furthermore, Campbell and Shiller have shown that if rents are integrated[2] of order one and farmland prices evolve according to the present value model then it is necessary that farmland prices must also be integrated of order one.

Tegene and Kuchler applied the cointegration technique and error correction representation to explain the movement of farmland prices in the U.S. Corn Belt (Illinois, Indiana, Iowa, Missouri and Ohio). They found that both farmland prices and rents were integrated of order one and were also cointegrated implying a long-run relationship between farmland values and rents. They also claim that the error correction model provides more efficient parameter estimates of the dynamics involved than the usual distributed lag models.

Tegene and Kuchler's results are based on the aggregate farmland prices and net rents (weighted by the state acreage) for the U.S. corn belt. Sherrick, Tirupattur, and Monke, however, argue that if the farmland prices themselves are not cointegrated across the states, their aggregation may cause "canceling out" effects and the loss of important state specific information. Accordingly, Sherrick et al., evaluated the time series properties of farmland prices from 1950 to 1990 for each of the eight states - Illinois, Indiana, Iowa, Missouri, Ohio, Minnesota, Nebraska and Wisconsin. They conclude that the farmland prices are stationary in levels for Illinois, Indiana and Iowa while their first differences are stationary for other states. Thus the existence of different time series properties across the states has made the use of aggregated data (Tegene and Kuchler) questionable. Falk, on the other hand, found that annual farmland price and cash rent time series data for Iowa from 1921 to 1986 were each first difference stationary. Similar investigation for three other sets of data - U.S. data from 1910 to 1990, U.S. data from 1950 to 1990, and Illinois data from 1950 to 1990 - however, produced different results (Clark, Fulton, and Scott). For Illinois and U.S. data (1950 - 1990), land values are integrated of order two while land rents are integrated of order one. In contrast, for U.S. data (1910 - 1990), land values are integrated of order one and the land rents are integrated of order zero. These findings are similar to those reported by Baffes and Chambers. As a result, Clark et al., conclude that the present value formulation of farmland values is not appropriate.

The time series properties of farmland prices and rents seem to be sensitive to the particular time series studied, geographic location and level of aggregation. For example, Illinois and Iowa are

---

[2] A farmland price time series with no deterministic component that has a stationary, invertible, ARIMA representation after differencing d times is said to be integrated of order d.

adjoining states that are part of the U.S. corn belt and, therefore, have similar land use patterns. However, the time series properties of farmland prices and rents are different. Furthermore, the application of cointegration techniques requires that both farmland price and rent be integrated of the same order. This paper investigates the appropriateness of the cointegration and error correction models in explaining Arkansas farmland price dynamics.

Theoretical Framework

The tests of cointegration have been used to establish the existence of long-run relationships between economic variables (Davidson, Hendry, Srba, and Yeo). The theory of cointegration states that if farmland prices, P_t, and rents, R_t, are integrated of the same order, d, then they are said to be cointegrated if their linear combination produces a stationary series (Engle and Granger). The linear combination of farmland prices and rents is represented by

$$u_t = P_t - \alpha - \beta R_t \tag{1}$$

Accordingly, if u_t is a stationary series then P_t and R_t are cointegrated and the relation $P_t = \alpha + \beta R_t$ is considered the long-run relationship between the two variables (Engle and Granger). u_t is the deviation from the long-run equilibrium and is interpreted as the rational forecast of the present value of all future changes in net rents (Falk).

The test of cointegration involves a stationarity test of each of the series separately. Dickey-Fuller unit root tests are appropriate for the stationarity tests and the standard procedure has been to first test for the unit root in the series levels. If the hypothesis of the presence of a unit root is not rejected, the first difference series is tested for the presence of a second root and so on. Since the Dickey-Fuller tests are based on at most one unit root, at least the first few tests in this sequence would not be theoretically justified if the series had more than one unit root (Sen). As a result, Dickey and Pantula have suggested a different order for performing tests. One should start with the largest order of integration (suppose k) and work down, i.e., decrease k by one each time the null hypothesis is rejected. Once the null hypothesis is not rejected, the testing procedure stops (Dickey and Pantula).

If P_t and R_t are integrated of order one then the cointegration between these two variables is tested by estimating the following OLS regression (cointegrating regression)

$$P_t = \alpha + \beta R_t + u_t \tag{2}$$

If P_t and R_t are not cointegrated, any linear combination of them will be nonstationary, and hence the residuals will be nonstationary. Accordingly, the null hypothesis of no-cointegration is that u_t is nonstationary.

The test of the hypothesis that u_t is nonstationary can be done in two ways. First, the test can be performed using the Durbin-Watson statistic (DW) from the cointegrating regression. If u_t is a random walk, the expected value of $(u_t - u_{t-1})$ is zero, so the DW should be close to zero. Thus one can simply test the hypothesis that DW is equal to zero. If the calculated DW is greater than the critical value (Engle and Granger, Table II) the hypothesis of no cointegration is rejected in favor of cointegration.

The second test, the Augmented Dickey-Fuller (ADF) test, however, is recommended by Engle and Granger based on the stability of critical values and power considerations. The ADF test involves running the following regression:

$$\Delta u_t = \delta\, u_{t-1} + \sum_{i=1}^{n} \theta_i \Delta u_{t-i} + v_t \tag{3}$$

where u_t is the residual series from the OLS regression of P_t on R_t. The order of n for the lagged terms is chosen such that the residual series, v_t, is white noise. The null hypothesis of no cointegration between P_t and R_t is rejected if δ is negative and significantly different from zero. For the ADF test, the ratio of the estimated δ to its estimated standard error from the OLS regression is compared to the critical values of τ in Fuller. Choice of the critical value, however, depends on whether the estimated model has an intercept and/or a linear trend.

If P_t and R_t are both integrated of order one without trends in the mean and are cointegrated then there exists an error correction model that is free from 'spurious regression' (Granger and Newbold). These error correction models (Engle and Granger) are presented in (4) and (5):

$$\Delta P_t = -\rho_1 u_{Pt-1} + \sum_{i=1}^{n} \eta_i \Delta P_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta R_{t-i} + e_{Pt} \tag{4}$$

$$\Delta R_t = -\rho_2 u_{Rt-1} + \sum_{i=1}^{n} \theta_i \Delta P_{t-i} + \sum_{i=1}^{n} \mu_i \Delta R_{t-i} + e_{Rt} \tag{5}$$

where $u_{Pt} = P_t - \alpha_P - \beta_P R_t$, $u_{Rt} = R_t - \alpha_R - \beta_R P_t$ and $|\rho_1| + |\rho_2| \neq 0$. e_{Pt} and e_{Rt} are white noise.

Engle and Granger suggest a two step estimation procedure for estimating the error correction model. In the first step the parameters of the cointegrating regression are estimated, and in the second step the residuals from the cointegrating regression are entered in the error correction model. Both steps require only single equation least squares and they are consistent for all parameters. Moreover, because in a bivariate cointegration, there must be causality in at least one direction, a significant coefficient for the error correcting term implies the direction of Granger causality. Therefore, incorporation of the error correcting term should contribute to improved forecast of at least one of the variables.

The literature indicates that different studies of the same relationship, which use different methods of testing, often report causality results that are not in conformity with one another (Hsiao; Jacobs, Leamer, and Ward). Such conclusions suggest that different methods of causality testing should be applied to the same data set. Accordingly, besides the causality implied by the error correcting term, the methods utilized by Granger (1969) and Sims are also used to examine the causality between farmland prices and rents.

Granger's notion of causality states that R_t causes P_t if the past lagged values of R_t can be used to predict P_t more accurately than merely by using the past lagged values of P_t. For Granger's causality, estimation of the following linear models is needed:

$$P_t = f(\text{Past lags of } R_t, \text{ Past lags of } P_t) \tag{6}$$

$$R_t = f(\text{Past lags of } P_t, \text{ Past lags of } R_t) \tag{7}$$

A unidirectional causality from R_t to P_t requires that all the coefficients of the past lags of R_t be jointly different from zero in (6) and that all the coefficients of past lags of P_t be jointly equal to zero in (7).

Sims's method, on the other hand, involves regressing farmland prices on past, current and future values of rent and vice versa:

$$P_t = f(\text{current value of } R_t, \text{ past lags of } R_t, \text{ future lags of } R_t) \tag{8}$$

$$R_t = f(\text{current value of } P_t, \text{ past lags of } P_t, \text{ future lags of } P_t) \tag{9}$$

Sims has shown that in a regression of P_t on past, current and future values of R_t, the null hypothesis of no causality from P_t to R_t is equivalent to all the coefficients of the future values of R_t being equal to zero. Thus Sims' method tests the null hypothesis that all the coefficients for future lags in (8) and (9) are zero.

Data

Farmland prices and cash rents from 1921 through 1992 for Arkansas are deflated to real terms and used in this study. Because the tenant agrees to pay a prespecified amount and bears all the risk from farming, cash rent is preferred to share lease as a measure of the net benefit of owning land. Moreover, cash rents have been found to predict land price changes more accurately than other measures of returns from land (Burt; Tweeten). The data from 1921 through 1959 are based on unpublished USDA data and the data from 1960 through 1988 from Jones and Hexem. The data from 1989 through 1992 are published in USDA, *Agricultural Resources: Agricultural Land Values Situation and Outlook Summary.*

The surveys on which farmland prices and cash rents are based are obtained at the beginning of the year. As a result, these nominal figures are expected to lag the general price level. The nominal farmland price and cash rent in year t, therefore, were deflated by dividing by the personal consumption expenditure component (PCE) of the GNP deflator in year t-1 to arrive at data in real terms.

Tests and Results

A necessary condition for the cointegration between farmland prices and rents is that each of the series must be integrated of the same order. Accordingly, Dickey-Fuller tests were performed following the sequential procedure recommended by Dickey and Pantula. Dickey and Pantula also suggest to include the intercept term when the alternative hypothesis is that the series is stationary in levels. The test procedure was carried out by considering the possibility of the presence of three unit roots as in Clark et al. The lagged dependent variables in each test are added to make the residuals from the regressions serially independent (Dickey, Bell and Miller):

(1) First the H_0 of three unit roots (integrated of order three) in time series X_t against the H_a of two unit roots (integrated of order two) is tested by estimating the model: $\Delta^3X_t = \alpha_0 + b_2\,\Delta^2X_{t-1} + \Sigma\,\pi_i\,\Delta^3X_{t-i} + z_t$. The τ-value associated with the estimated b_2 is compared against the critical value of τ in Fuller. If the H_0 is rejected the H_0 of two unit roots is tested otherwise the H_0 of three unit roots is not rejected and the testing procedure stops.

(2) The H_0 of two unit roots against the H_a of one unit root is tested by estimating the model: $\Delta^3X_t = \alpha_0 + b_1\,\Delta X_{t-1} + b_2\,\Delta^2X_{t-1} + \Sigma\,\pi_i\,\Delta^3X_{t-i} + z_t$. The τ-value associated with the estimated b_1 is compared to critical value of τ in Fuller. If the H_0 is rejected the H_0 of one unit root is tested otherwise the H_0 of two unit roots is not rejected and the testing procedure stops.

(3) The H_0 of one unit root against the H_a of zero unit root is tested by estimating the model: $\Delta^3X_t = \alpha_0 + b_0\,X_{t-1} + b_1\,\Delta X_{t-1} + b_2\,\Delta^2X_{t-1} + \Sigma\pi_i\,\Delta^3X_{t-i} + z_t$. The τ-value associated with the estimated b_0 is compared to the critical value of τ_μ in Fuller. If the H_0 of one unit root is not rejected the testing procedure stops.

The results of Dickey-Fuller tests are presented in Table 1. The results of test numbers 1 and 2 in Table 1 reject the null hypotheses of three and two unit roots in each of the series. The result of test number 3, however, does not reject the null hypothesis of one unit root, i.e., the series are each stationary in their first differences. The significance levels of the Box-Q statistics indicate that the residuals in all cases are white noise. These results are consistent with those of Falk for Iowa data but at odds with those of Clark et al. for Illinois data.

Table 1. Dickey-Fuller Test Results for Arkansas Farmland Price and Cash Rent Series[a]

Test Number	Test	Farmland Prices	Cash Rents
1	H_0: 3 unit roots vs. 2 unit roots	-11.669* (0.997)	-12.611* (0.433)
2	H_0: 2 unit roots vs. 1 unit root	-4.114* (1.00)	-6.842* (0.701)
3	H_0: 1 unit root vs. zero unit root	-1.416 (1.00)	-1.430 (0.734)

[a] τ-values are presented for the corresponding coefficients. The numbers in parentheses are the significance levels of Box-Q statistics from Dickey-Fuller regressions.

* Indicates significance at the one percent level.

Given that farmland prices and cash rents are both integrated of order one, the test for cointegration proceeded as follows. First, the cointegrating regressions were estimated by OLS. The estimated results are:

$$P_t = \underset{(-9.383)}{-688.09} + \underset{(16.361)}{30.412}\, R_t \qquad R^2 = 0.795 \qquad DW = 0.4979 \tag{10}$$

$$R_t = \underset{(28.581)}{25.873} + \underset{(16.361)}{0.026}\, P_t \qquad R^2 = 0.795 \qquad DW = 0.6386 \tag{11}$$

where the figures in parentheses are t-ratios. The cointegrating regression Durbin-Watson tests (CRDW) of 0.4979 in (10) and 0.6386 in (11) reject the null hypothesis of no cointegration between the variables.

The Augmented Dickey-Fuller (ADF) tests were also performed on the residuals of the estimated cointegrating equations for cointegration. Since the lagged terms of the dependent variables were found to be insignificant, instead of ADF, Dickey-Fuller tests were performed. The estimated Dickey-Fuller regression results for the residuals u_{Pt} of (10) and u_{Rt} of (11) are presented in (12) and (13), respectively:

$$\Delta u_{Pt} = \underset{(-3.046)}{-0.245}\, u_{Pt-1} \tag{12}$$

$$\Delta u_{Rt} = \underset{(-3.520)}{-0.315}\, u_{Rt-1} \tag{13}$$

where the figures in parentheses are τ-ratios. Since the computed τ-ratios are less than the tabulated critical value of -1.95 (Fuller) in both equations, the Dickey-Fuller tests reject the null hypotheses that the residuals are nonstationary (noncointegration) implying that the series are cointegrated.

Since farmland prices and cash rents are cointegrated there is a long-run relationship between them. To represent the short-run adjustments in farmland prices, an error correction model is estimated for P_t and R_t separately. The results are:

$$\Delta P_t = \underset{(0.363)}{2.238} - \underset{(-2.624)}{0.131}\, u_{Pt-1} + \underset{(2.164)}{0.260}\, \Delta P_{t-1} \quad (14)$$

$$\Delta R_t = \underset{(0.109)}{0.048} - \underset{(-1.43)}{0.160}\, u_{Rt-1} \quad (15)$$

where the figures in parentheses represent t-ratios. The lag structure was chosen based on the significance of lagged terms. The error correcting term u_{Pt-1} is significantly different from zero at the one percent level in (14) while u_{Rt-1} is not significant in (15). Since farmland prices and rents are cointegrated, these results indicate that rent is weakly exogenous and, therefore, Granger causality runs from rents to farmland prices.

The causality from rents to farmland prices is also investigated by utilizing the methods outlined in Granger and Sims. For the Granger method, the following regression models were estimated:

$$P_t = f(\text{2 past lags of } R_t, \text{ 2 past lags of } P_t) \quad (16)$$

$$R_t = f(\text{2 past lags of } P_t, \text{ 2 past lags of } R_t) \quad (17)$$

$$P_t = f(\text{2 past lags of } P_t) \quad (18)$$

$$R_t = f(\text{2 past lags of } R_t) \quad (19)$$

Equations (18) and (19) represent the restricted versions of (16) and (17) respectively. The choice of lag structure was based on the Akaike Information Criterion (AIC). The Granger method results are presented in Table 2. The results indicate Granger causality runs from rents to farmland prices.

Table 2. Granger Causality Test Results

Null Hypothesis	F-Ratios	Results
No Causality from Rents to Farmland Prices	3.905* (2,65)[a]	Reject H_0
No Causality from Farmland Prices to Net Rents	2.256 (2,65)[a]	Fail to reject H_0
Causal Inference	Cash Rents to Farmland Prices	

[a] Figures in the parentheses are the degrees of freedom.

* Significant at the five percent level.

To utilize the Sims' method, the two-sided regression models in (20) and (21) were estimated together with their restricted versions, (22) and (23), respectively. The choice of lagged and lead terms was based on AIC.

$$P_t = f(R_t, \text{ 3 past lags of } R_t, \text{ 3 future lags of } R_t) \quad (20)$$

$$R_t = f(P_t, \text{ 3 past lags of } P_t, \text{ 3 future lags of } P_t) \quad (21)$$

$$P_t = f(R_t, \text{ 3 past lags of } R_t) \quad (22)$$

$$R_t = f(P_t, \text{ 3 past lags of } P_t) \quad (23)$$

The results of the Sims' test are presented in Table 3. In the test for causality from farmland prices to rents (20), the null hypothesis is that farmland prices do not cause rents. Rejection of the null hypothesis implies that farmland prices cause rents. Similarly, in the test for causality from rents to farmland prices (21), the null hypothesis is that rents do not cause farmland prices. Rejection of the null hypothesis implies that rents cause farmland prices. The results in Table 3 indicate that the causality between farmland prices and rents is unidirectional from rents to farmland prices.

Table 3. Sims Causality Test Results

Null Hypothesis	F-Ratios	Results
No Causality from Farmland Prices to Net Rents	0.80 (3,58)[a]	Fail to reject H_0
No Causality from Net Rents to Farmland Prices	3.00* (3,58)[a]	Reject H_0
Causal Inference	Cash Rents to Farmland Prices	

[a] Figures in the parentheses are the degrees of freedom.

* Significant at the five percent level.

The results of each of the three tests imply Granger causality from rents to farmland prices. Accordingly, the data were also used to investigate the movements in farmland prices that were attributed to rents. Following Alston, the percentage change in the growth of real land prices is compared to the percentage change in the growth in real rents with the difference between the two attributed to other factors. The results for the period 1922 through 1992 are:

Mean Percentage Change in Real Farmland Prices = 1.6409 (94.90)

Mean Percentage Change in Real Rents = 0.6467 (115.06)

Difference Between the Two Mean Percentages = 0.9942.

The figures in parentheses are the sample variances. The significance of the difference between the two sample means is tested using the t-test. The computed t-ratio for the difference is 0.574. Since the computed t-ratio is less than the tabulated critical value for any reasonable significance level, the null hypothesis of zero difference between the sample means is not rejected. In other words, the mean growth rate of real farmland price is not significantly different from the mean growth rate of real rent implying that the movements in farmland prices are fully explained by the movements in rents.

Concluding Comments

Results from previous studies display differences in the time series properties of farmland prices and cash rents. These differences may be the result of differences in the particular time series studied, geographic location, aggregation level or methodology. The results from the study presented here show that Arkansas farmland prices and cash rents for the period 1922 through 1992 are cointegrated of order one. Thus a long-run relationship between farmland price and cash rent is supported since these time series are cointegrated. In addition, since both farmland prices and cash rents are cointegrated of order one, the present value model for asset valuation is supported. Although these results are consistent with some studies (Tegene and Kuchler), the results are inconsistent with other studies (Clark et al.; Baffes and Chambers). The particular reasons for the different results among studies should be identified in the future.

The error correction model is used in this study to better explain the short-run adjustments in farmland prices. The results from the error correction model and Granger and Sims causality tests support Granger causality running from cash rents to farmland prices. Also, the mean growth rate of real farmland price is found to be insignificantly different from the mean growth rate of real cash rent which implies that movements in farmland prices are fully explained by movements in cash rents.

While the results from this study support the present value model for asset valuation, additional research is needed. The underlying factors causing changes in cash rents should be identified. These underlying factors such as input and output prices, mortgage rates, discount rates, taxes, inflation and technological change could be used to explain the short-run dynamics between farmland price and cash rent.

References

Alston, J.M. "An Analysis of Growth of U.S. Farmland Prices, 1963-82." *American Journal of Agricultural Economics* 68(1986):1-9.

Baffes, J. and R.G. Chambers. "Rational Bubbles and Land Prices." Working Paper No. 89-37, Department of Agricultural and Resource Economics, University of Maryland, College Park, Maryland, 1989.

Barry, P.J. "Capital Asset Pricing and Farm Real Estate." *American Journal of Agricultural Economics* 62(1980):549-53.

Burt, O.R. "Econometric Modelling of the Capitalization Formula for Farmland Prices." *American Journal of Agricultural Economics* 68(1986):10-26.

Campbell, J.Y., and R.J. Shiller. "Cointegration and Tests of Present Value Models." *Journal of Political Economy* 95(1987):1062-88.

Castle, E.N., and I. Hoch. "Farm Real Estate Price Components, 1920-78." *American Journal of Agricultural Economics* 64(1982):8-18.

Clark, J.S., M. Fulton, and J.T. Scott, Jr. "The Inconsistency of Land Values, Land Rents, and Capitalization Formulas." *American Journal of Agricultural Economics* 75(1993):147-55.

Davidson, J., D.F. Hendry, F. Srba, and S. Yeo. "Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom." *Economic Journal* 88(1978):661-92.

Dickey, D.A., and W.A. Fuller. "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root." *Econometrica* 49(1981):1057-72.

Dickey, D.A., and S.G. Pantula. "Determining the Order to Differencing in Autoregression Processes." *Journal of Business and Economic Statistics* 5(1987):455-61.

Dickey, D.A., W.R. Bell, and R.B. Miller. "Unit Root Tests in Time-Series Models: Tests and Implications." *The American Statistician* 40(1986):12-26.

Engle, R., and C.W.J. Granger. "Cointegration and Error Correction: Representation, Estimation and Testing." *Econometrica* 55(1987):251-76.

Falk, B. "Formally Testing the Present Value Model of Farmland Prices." *American Journal of Agricultural Economics* 73(1991):1-10.

Featherstone, A.M., and T.G. Baker. "An Examination of Farm Sector Real Estate Dynamics." *American Journal of Agricultural Economics* 69(1987):532-46.

Feldstein, M. "Inflation, Portfolio Choice, and the Prices of Land and Corporate Stock." *American Journal of Agricultural Economics* 62(1980):910-16.

Fuller, W.A. *Introduction to Statistical Time Series.* Wiley, 1976.

Granger, C.W.J. "Developments in the Study of Cointegrated Economic Variables." *Oxford Bulletin of Economics and Statistics* 48(1986):213-18.

Granger, C.W.J., and P. Newbold. *Forecasting Economic Time Series.* Academic Press, New York, 1977.

Granger, C.W.J. "Investigating Causal Relations by Econometric Models and Cross-Spectoral Methods." *Econometrica* 37(1969):424-38.

Hsiao, C. "Causality Tests in Econometrics." *Journal of Economic Dynamics and Control* 1(1979): 321-46.

Jacobs, R.L., E.E. Leamer, and M.P. Ward. "Difficulties with Testing for Causation." *Economic Enquiry* 17(1979):401-13.

Jones, J., and R.W. Hexem. "Cash Rents for Farms, Cropland, and Pasture, 1960-89." USDA, Statistical Bulletin 813, Washington, DC, October 1990.

Just, R.E., and J.A. Miranowski. "Understanding Farmland Price Changes." *American Journal of Agricultural Economics* 75(1993):156-68.

Klinefelter, D.A. "Factors Affecting Farmland Values in Illinois." *Illinois Agricultural Economic Research* 13(1973):27-33.

Melicher, E. "Capital Gains versus Current Income in the Farming Sector." *American Journal of Agricultural Economics* 61(1979):1085-92.

Robison, L.J., D.A. Lins, and R. Venkataraman. "Cash Rents and Land Values in U.S. Agriculture." *American Journal of Agricultural Economics* 67(1985):794-805.

Sen, D.L. "Robustness of Single Unit Root Test Statistics in the Presence of Multiple Unit Root Tests." Unpublished Ph.D. Dissertation, Department of Statistics, North Carolina State University, 1985.

Shalit, H. and A. Schmitz. "Farmland Accumulation and Prices." *American Journal of Agricultural Economics* 64(1982):710-19.

Sherrick, B.J., V. Tirupattur, and J.D. Monke. "Cointegration Analysis of Farmland Prices." Selected Paper presented at the AAEA Annual Meeting, Baltimore, 1992.

Sims, C.A. "Money, Income and Causality." *American Economic Review* 62(1972)540-52.

Tegene, A., and F, Kuchler. "An Error Correcting Model of Farmland Prices." *Applied Economics* 23(1991):1741-47.

Tweeten, L. "A Note on Explaining Farmland Price Changes in the Seventies and Eighties." *Journal of Agricultural Research* 38(1986):25-30.

U.S. Department of Agriculture, Economic Research Service. *Agricultural Resources: Agricultural Land Values, Situation & Outlook Summary.* AR 5-93, Washington, DC, May 6, 1993.