A Pooled Time-Series Cross-Section Analysis of Land Prices

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Based on a theoretical formulation of land price formation as an economic rent to a fixed input, a single equation econometric model is specified and estimated to explain land prices in five Iowa crop reporting districts. It identifies the influence of farm prices, inflationary pressures, and land quality on the price of land.

The determinants of farm land prices have been the subject of considerable research in agricultural economics [Wallace; Tweeten and Martin; Herdt and Cochrane; Reynolds and Timmons]. Much work was concentrated in the 1960's, but the rapid land appreciation experienced in the last decade has contributed to a resurgence of interest [Harris; Pope et al; Brake and Melichar; Melichar; Reinsel and Reinsel]. Indeed, land values in the United States tripled in the 1970's.

Pope et al. have recently examined the plausibility of a number of previously published models [Reynolds and Timmons; Tweeten and Martin; Herdt and Cochrane; Klinefelter] as explanations of recent farm land market events, and studied their predictive ability. Reestimation of each model with additional data produced many sign reversals and insignificant parameter estimates, particularly in the simultaneous equation models. Their findings suggest important recent structural changes in the farm land market not adequately explained by any of the models. However, the empirical results of the single equation (modified Klinefelter) model were at least as plausible as the simultaneous equation models, and its predictive performance was decidedly better.

The Klinefelter model relates variations in land prices to net returns, average farm size, number of transfers, expected capital gains, and a GNP deflator. Both because of its simplicity and its predictive performance, the single equation model is particularly attractive for further investigation of farm land prices.

A common feature of all the earlier models, whether simultaneous or single equation, has been a reliance either on a single dominant product price [Harris] or on some measure of net farm income as a definition of returns to land. The latter often requires extensive adjustments to conventional data sources before it is useful as an indicator of returns to land. None of the earlier models has attempted to estimate the separate impact of various product prices on land prices even though the composition of commodities produced may have changed markedly over the data period.

The purpose of this study is to disaggregate the effects of net income on land prices in an area characterized by multiple product production. A simplified single equation model of land prices is derived from the theoretical foundation of price-taking profit-maximizing firms producing multiple products. The relationship between land value and commodity prices is examined in this context. Estimation is aided by this theoretical formulation as

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data for the relevant explanatory variables (or their close proxies) are readily available. The model is used to explain land price variations over time and across areas in Iowa during the period 1967 to 1977.

A Theoretical Approach

Since the supply of land is so inelastic, even over very long adjustment periods, land can be considered essentially a fixed factor in agricultural production. Thus, the price of land can be appropriately modeled as an economic rent rather than simultaneously solving for the intersection of land supply and demand as though it were a variable factor. While the latter approach has been taken in a number of prior studies, the key determinants of land prices are determinants of a rent.

Consider a competitive firm facing a technology represented by a multi-product-multifactor transformation function at time t,

$$(1) \qquad f(Y_t, X_t, S_t) = 0$$

where Y_t is a $(J \times 1)$ vector of outputs, X_t is a $(K \times 1)$ vector of variable inputs[1], and S_t is a vector of parameters characterizing technology at time t. Denote by p_j the price of y_j (the j^{th} output) and by r_k the price of x_k (the k^{th} input). Then the profit function of the firm at time t is

$$(2) \; \pi_t = \sum_{j=1}^{J} p_{jt}\, y_{jt} - \sum_{k=1}^{K} r_{kt}\, x_{kt}$$

Assuming that the objective function of the firm is to maximize profit, the firm input demand and output supply functions are respectively, $x^*_{kt} = x_{kt}(R_t, P_t, S_t)$ and $y^*_{jt} = y_{jt}(R_t, P_t, S_t)$ where $R_t = (r_{1t}, \ldots, r_{Kt})$ and $P_t = (p_{1t}, \ldots, p_{Jt})$. Substituting these optimum inputs and outputs into equation (2) gives the firm indirect profit function

$$(3) \; \pi^*_t = \sum_{j=1}^{J} p_{jt}\, y^*_{jt} - \sum_{k=1}^{K} r_{kt}\, x^*_{kt}$$

Equation (3) is the firm quasi-rent at time t. It is linear homogeneous in prices, an increasing function of output prices, and a decreasing function of input prices [Varian]. The quasi-rent is the income that is left after all variable inputs have been paid. Thus, it is the remuneration of the fixed factors. Land remains essentially fixed in aggregate supply longer than other farm inputs and so is typically regarded as the major fixed factor that obtains an economic rent. However, there are other relevant fixed factors also, e.g., management, operator labor and structures. If we denote by α_t the expected proportion of net returns, or quasi-rent, of farming activities that goes to land then $\alpha_t\pi_t{}^*$ is the expected value of return to land in year t.

Since land provides a service over time, the value of land at time t=0 is the present value[2]

$$(4) \qquad L = \sum_{t=1}^{T} \frac{1}{(1+i)^t}\, \alpha_t\, \pi^*_t$$

where T is the length of the planning horizon and i is the discount rate reflecting time preference. Of course, different land qualities would imply different production functions, different rents and different land values. Also, since time is involved in equation (4), it follows that the current economic

[1]The transformation function and subsequent optimal supply-demand equations rightfully include the quantity of fixed factors as an additional argument. However, since land is treated as the main fixed factor and, in aggregate, its quantity does not change much over the period of analysis, fixed factors are not included in the transformation function for notational convenience.

[2]The quasi-rent for the first time period is also discounted under the assumptions that present value is computed for the beginning of the first time period, income is received at the end of the period, and interest charges on costs incurred during the period are subtracted along with other costs from current income before discounting.

situation as well as expectations about the future concerning product and variable input prices and technology may influence land values.[3] To illustrate, assume that the return to land, $\alpha_t\pi_t^*$, is expected to increase over time at a constant rate, β, i.e. $\alpha_t\pi_t^* = (1+\beta)^t \alpha_0\pi_0^*$, where $\beta<i$. Then, when T becomes large, the value of land in (4) is

$$(5) \qquad L = \frac{1+\beta}{i-\beta} \cdot \alpha_0\pi_0^*$$

Clearly, from (5) an increase in current returns increases land price. Also, since

$$\frac{\partial L}{\partial \beta} = \frac{1+i}{(i-\beta)^2}\alpha_0\pi_0^* > 0,$$

it follows that any factor that tends to increase β will increase current land value. For example, any expectation of future output price increases, variable input price decreases, or future technological progress would put upward pressure on land prices.

Melichar has shown that the proportion of the total return that goes to production assets has risen sharply over the last two decades. He argues that the substitution of capital for labor may be one of the major factors explaining this trend. Since this substitution is largely due to technological and market price changes, it appears reasonable to assume that the parameter α_t is determined by such variables. In this case, substituting (3) into (4) yields an equation of the general form

$$(6) \qquad L = f[R_1, R_2, \ldots, R_T; P_1, P_2, \ldots, P_T; S_1, S_2, \ldots, S_T; i]$$

where R_t, P_t $(t=1,\ldots,T)$ are the expected future price vectors, and S is a set of parameters measuring technology. Expression (6) gives the price the firm is willing to pay for a given piece of land that has a multi-product use according to (1).

[3]Melichar has emphasized that an expected growth in returns to land can play a prominent role in increasing land prices.

Application to Iowa Land Prices

Expression (6) provides a basis for the investigation of land prices. The case of Iowa has been chosen for two reasons. First, cross-section and time-series data of good quality are available in Iowa [Harris, et al.]. Second, the Iowa economy is predominantly agricultural, so the impact of urban activities on land prices is expected to be small. Rather than formally testing the latter hypothesis, its validity will be assessed by the explanatory power and performance of the estimation equation which excludes variables directly measuring urban competition for land.

An aggregate net returns measure has been used to represent commodity prices in most prior land value studies. Such an approach has the disadvantage that the impact on land prices of different growth patterns among commodities cannot be differentiated. Between 1967 and 1977, corn price in Iowa increased by 75 percent, while soybean price increased by 161 percent and hog price by 112 percent [Iowa Farm Outlook Charts]. These changes have been associated with important modifications in commodity proportions. For instance, the proportion of Iowa harvested acreage in soybeans has varied from less than 20 percent to more than 40 percent in the last two decades. Since, as argued in the previous section land value is influenced by both the level and expected growth of net returns, it appears important to identify the different sources of expected growth in a model of land prices. This is done in this paper by introducing commodity-specific information in the modeling approach. The analysis concerns land prices in five of the nine crop reporting districts of Iowa: (1) Northwest, (2) North Central, (3) West Central, (4) Central and (5) East Central. They have been chosen because the three major commodities produced in Iowa, corn, soybeans and hogs, are also the major agricultural commodities in each of these districts. Thus, the price vector P in equation (6) includes corn price, soybean price and hog price.

Although Iowa is one of the major agricultural states in the U.S., both prices for its products and prices for its variable inputs are determined within the larger national market. Because the aggregate supply of individual inputs in such a market is likely not perfectly elastic, input prices may be functionally related to product prices via their derived demands. To demonstrate, the partial equilibrium industry demand function for the k^{th} input, denoted by x_k^d (R_t, P_t, S_t) is simply the sum of the input demand functions x_{kt}^* over all firms in the industry. Considering the market supply functions for inputs, x_k^s (r_{kt}), $k=1,\ldots,K$, the equilibrium input prices can then be obtained by solving the input market supply and demand functions for R_t:

$$(7) \qquad R_t = R(P_t, S_t)$$

Equation (7) gives the equilibrium input prices at time t as they adjust through the market to changes in output prices and technology. Thus, substituting (7) into (6) gives,

$$(8) \quad L = f[R(P_1, S_1),\ldots,R(P_T, S_T); P_1,\ldots,P_T; S_1, S_2,\ldots,S_T; i]$$

Expression (8) shows that the "total effect" of an output price change on land value (dL/dp_{jt}) is the sum of the direct effects $(\partial L/\partial p_{jt})$ and indirect effects $(\partial L/\partial R_t)$ $(\partial R_t/\partial p_{jt})$. Such "total effect" measures can be used as a predictive device (Buse). Their use in policy analysis has been illustrated recently by Gardner in the context of multiproduct supply response. In our case, we will focus on the relationship between product prices and land value. Consequently, in order to directly estimate the total effects of output prices, variable input prices are not included in the model, as expression (8) is a function only of technology and product prices P, i.e. corn, soybean and hog prices.

Technological progress over time, S_t, is represented initially by corn yield.[4] Dummy variables for crop reporting districts are included as proxies for cross-sectional differences in land quality. Two other measures are included in revisions of the model: the dummy variables are replaced by the "corn suitability rating", and soybean yield is included along with corn yield to reflect additional temporal changes in technology. The "corn suitability rating" is a variable developed by soil and crop scientists in midwestern states [Fenton; Fenton, et al.] to measure changes in soil and climatic quality over space. These ratings provide an index for comparing farm land in different locations in Iowa. They measure the integrated effects of numerous factors that influence the yield potential and frequency of soil use for corn and soybean production at a specified management level. More specifically, they reflect soil, slope and weather differences, and difference in response to modern technology [Fenton, et al.].

Inflation is expected to have some influence on land prices either directly or indirectly through the discount rate i in expression (8).[5] For this reason, the consumer price index is introduced in the model as a measure of general inflationary pressures. Prices are not deflated by the consumer price

[4]Precise measures of technology are not available. Yields pick up input substitution effects as well as changes in the underlying technology. The major alternative, the time variable, typically is used to represent constant absolute or relative technical change over time but is not well suited to measuring lumpy or irregular technical change.

[5]Inflation (or expected inflation) may result in either higher or lower farm land prices depending on how it affects after tax net returns to agriculture, the proportion of net returns that goes to land, and the discount rate. If it affects only the discount rate, an increase in inflation tends to decrease land values. However, if an increase in food prices constitutes a part of the inflationary pressure, one may expect net returns from farming to increase with inflation. If variable input prices do not rise as rapidly as product prices, it is also possible for inflation to yield a higher proportion of net returns as a quasi-rent to land. Thus, whether inflation (or the expectation of it) increases or decreases land values is an empirical question and cannot be unambiguously signed as a theoretical hypothesis in the absence of further assumptions.

index since that would restrict the profit function to be homogeneous of degree zero in product prices and general price level. While there are some valid theoretical arguments to support such a restriction when both product and variable input prices are included in the estimation equation, none exist to justify imposing zero homogeneity in product prices and general price level alone.

Finally, (8) involves expectations about the future. Ideally, one would like to formulate an operational notion of future prices based on rational expectations arguments (Muth) because all learning evident in the market is incorporated in such expectations. However, because of the difficulty of specifying structures generating rational expectations, a simple adaptive structure is assumed here. On this basis, the following model has been specified

$$(9)\ L_{dt} = \alpha_0 + \alpha_1 [b\ PCORN_{t-1} + (1-b)PCORN_{t-2}] + \alpha_2 [b\ PSOY_{t-1} + (1-b)\ PSOY_{t-2}] + \alpha_3 [b\ PHOG_{t-1} + (1-b)PHOG_{t-2}] + \alpha_4\ YCORN_{t-1} + \alpha_5\ CPI_{t-1} + \alpha_6\ DV_2 + \alpha_7\ DV_3 + \alpha_8\ DV_4 + \alpha_9\ DV_5,$$

where t denotes time; L_d denotes the land price in the d^{th} district, PCORN, PSOY and PHOG are, respectively, the Iowa farm price for corn, soybeans and hogs; YCORN is the Iowa corn yield; CPI is the consumer price index, and DV_d is a dummy variable taking the value of 1 for the d^{th} district and zero otherwise. All variables are in logarithmic form.

The specification of the lag structure in (9) assumes a one-year delay in the adjustment of land price to the yield variable and the CPI. The lag distribution for the price variables is slightly more complex. First, in preliminary tests, attempts to introduce prices lagged more than two years gave insignificant coefficients. On this basis, assuming a one-year delayed response to price, prices lagged 1 and 2 years were included in the model. Second, we tested whether the shape of the lag structure was the same for corn, soybeans and hog prices and failed to reject this hypothesis at the 5 percent significance level. Thus, the specification presented in (9) assumes an identical distributed lag shape for the three prices.

Equation (9) provides a simple specification of land price behavior. It is constructed to estimate the total effects of major agricultural product prices and to determine whether it is possible to explain farm land prices in this market from a competitive model of agricultural production. Using annual pooled observations from 1967 to 1977 for the five regions, it is estimated by nonlinear regression, using the Marquardt algorithm. The results are presented in Table 1.

The model explains 99.2 percent of the variations in land prices within the estimation period. All variables except DV_5 are significant at the 5 percent level. The latter is significant at the 10 percent level. Table 1 shows that the product prices lagged two years have more impact on land prices than product prices lagged one year, as the estimate of b is .3611. This suggests a fairly slow adjustment.

All the elasticities of land price with respect to output prices have the expected sign. They are .42, .49 and .37 for corn, soybeans, and hogs, respectively. The relative magnitude of these elasticities appears plausible. The corn price elasticity is larger than the hog price elasticity, which corresponds to the rank ordering of their values of production: in 1977, Iowa value of production for corn and hogs was $2.2 and $2.0 billion respectively. Soybean price has a greater elasticity although the value of soybean production was lower ($1.4 billion for Iowa in 1977). This may be due to the growth factors associated with the sharp increase in soybean acreage in Iowa in the last twenty years. A one percent sustained increase in the price of all commodities would increase land price by 1.27 percent. Thus, proportion-

TABLE 1. Estimates of Equation (9)[a]

INT	PCORN	PSOY	PHOG	YCORN	CPI	DV_2	DV_3	DV_4	DV_5
−1.9815	.4184	.4852	.3711	.8880	.5406	.0544	−.1741	.0802	−.0409
(.7519)	(.1460)	(.0884)	(.1360)	(.1335)	(.1367)	(.0219)	(.0219)	(.0219)	(.0219)
b = .3611									
(.0832)									
R^2 = .992									

[a]Asymptotic standard errors are in parentheses below the parameter estimates.

ate increases in major product prices accompanied by the corresponding adjustments in input prices are translated into a greater relative increase in land prices.

The elasticity of land price with respect to corn yield is .89 which suggests that technological progress has a very strong and significant impact on land rent. Also, a one percent increase in the consumer price index is associated with a .54 percent increase in land price. Thus, while it is possible to have general inflation without a corresponding increase in farm land prices, such does not appear to be the case in Iowa; land prices are positively correlated with the consumer price index.

The coefficients of the DV_d variables estimate the impact of all regional differences from region 1, i.e., soil, climate, etc., on land prices. Because soil and crop scientists in Iowa and other Midwestern states have developed an explicit measure of soil and climatic quality for each county in the state, the "corn suitability rating" is examined as an alternative to the dummy variables. To determine the extent to which this measure is correlated with the estimates of regional price differences, the latter (estimated coefficients of DV_d's) are regressed on the simple average of county corn suitability ratings (CSR) in each district. The regression results are presented in Table 2. They show that the corn suitability ratings explain 83 percent of the variations in land prices between districts. Although there are few degrees of freedom, both the intercept and the slope coefficient have low standard errors, implying that a reasonably narrow confidence interval could be established for predicting

TABLE 2. Regression of the Coefficients of the DV_d's on the Corn Suitability Ratings.[a]

INT	CSR
68.446	54.020
(1.292)	(14.202)
R^2 = .83	

[a]Standard errors are in parentheses below the regression estimates.

regional price differences based only on the CSR.

To further examine the value of the CSR variable in the estimation of land prices and to determine its impact on the other parameter estimates, it is substituted for the district dummy variables in equation (9), and the model is reestimated. The results are reported in Table 3 (revised model A). Except for the intercept, all parameter estimates are the same as in the original model to the third decimal place. This suggests fairly robust estimates of the elasticities. Standard errors are a little higher, but all parameters are significant at the 5 percent level. Goodness of fit as measured by R^2 is only slightly lower. These results provide an explicit estimate of the influence of soil quality, as measured by the CSR, on land prices: a 1 percent increase in the CSR increases land prices by 1.05 percent. Testing the hypothesis that the elasticity of land price with respect to CSR is equal to 1, we conclude that, given a 5 percent level of significance, land price is a linear homogeneous function of the CSR.

At the suggestion of one of the reviewers, a second technology variable, soybean yield (YSOY), was included along with corn yield and the CSR in a further revision. The parameter estimate on soybean yield was not significant at the 10 percent level, and standard errors on most other variables were substantially increased (see table 3, revised model B). Thus, while high collinearity among independent variables was a potential problem in all three models, it appears to have affected the quality of the estimates only in revision B. Although prices and the CPI show considerable correlation, the low standard errors on all parameters estimated imply that collinearity is not a major problem in either model. Along with the high R^2 values and parameter consistency, the quality of estimates in those equations appears to be very good.

Finally, in order to validate the model, predicted land prices from the models are compared with the actual prices. This comparison is charted in Figure 1 for actual and

TABLE 3. Estimates of the Revised Models.[a]

Revised Model	INT	PCORN	PSOY	PHOG	YCORN	YSOY	CPI	CSR	b	R^2
A	−6.4365	.4184	.4852	.3711	.8879	-	.5406	1.0544	.3611	.987
	(1.021)	(.1782)	(.1076)	(.1658)	(.1620)	-	(.1661)	(.1089)	(.1018)	
B	−7.507	.2461	.6312	.6264	.8346	.6391	.1612	1.0545	.2425	.988
	(3.219)	(.3876)	(.2711)	(.6063)	(.2603)	(1.0556)	(.7487)	(.1048)	(.2616)	

[a]Asymptotic standard errors are in parentheses.

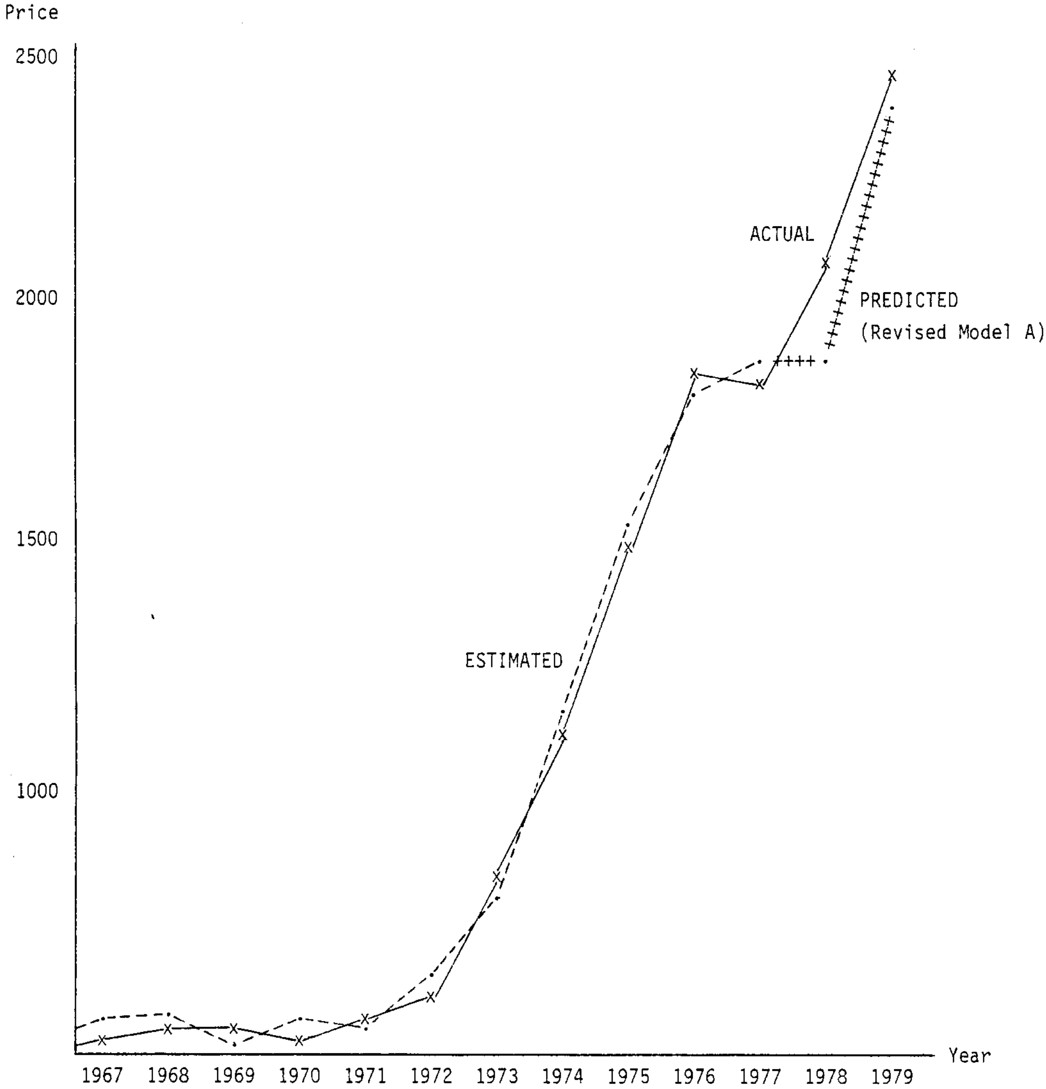

Figure 1. Actual and Predicted Land Prices in Iowa-Central District.

predicted land prices in one district using one model over the estimation period (1967-77) and for two additional forecast years (1978-79). The model tracks actual land prices very closely over the estimation period, substantially underpredicts in 1978 and then closely forecasts actual 1979 price. The large forecast error for 1978 is not surprising given the lagged structure of the model and the unusual single-year downturn in 1977 following several years of rapid appreciation in land prices.

Predictions using both models are contrasted with actual land prices in all districts for the forecast years 1978-79 in Table 4. They consistently under-predict 1978 land prices but give more accurate predictions for 1979. The average forecast error for both years is 11.1 percent for Revised Model A and 9.2 percent for Revised Model B. While these magnitudes seem high, they are lower than the best predictive performance of any model examined by Pope, et al. for the 1973-75 period. Given the unusual circumstances of the forecast period, these simple models perform generally quite well.

Comparison with Previous Research

Because of specification, location and time differences, comparison of our results with earlier studies is difficult. For example, considering only specification differences, Klinefelter and also Reynolds and Timmons use deflated prices and income while Herdt and Cochrane and our model use the general price level as a separate explanatory variable. While Tweeten and Martin, and Reynolds and Timmons include net farm income in their model, Herdt and Cochrane use the ratio of the index of prices received by farmers to the index of prices paid by farmers to explain the variations in land prices. Also, in order to capture the influence of expectations about the future, Klinefelter, and Reynolds and Timmons introduce a capital gain variable, while Herdt and Cochrane, and our model use a distributed lag on farm prices. Finally, although our approach uses a simple specification, it is the only one that explicitly examines the effects of multiple-product use of the land. Thus, only limited comparisons of results follow.

Our high estimated elasticity of land price with respect to corn yield is in agreement with Herdt and Cochrane's finding that productivity is an important factor influencing land prices. Also, our results give further inferential evidence about the positive relationship existing between support-price policies and land values. From a policy point-of-view, it has the advantage of providing a direct estimate of the influence of a change in

TABLE 4. Model Predictions of Land Prices.

	District					Average Prediction Error
	1	2	3	4	5	
			($/acre)			(%)
1978:						
Actual	1932	2146	1623	2078	1826	-
Predicted Revised Model A	1556	1748	1450	1807	1543	15.44
Predicted Revised Model B	1615	1814	1504	1875	1602	12.25
1979:						
Actual	2363	2548	1887	2438	2163	-
Predicted Revised Model A	2043	2296	1904	2372	2026	6.67
Predicted Revised Model B	2284	2566	2128	2652	2265	6.06

a particular commodity price on land prices. For example, a change in the corn support rate that raises its expected price 10 percent can be expected to increase land prices between 2.5 and 4.2 percent.

Our estimated elasticities of Iowa land prices with respect to the general price level are lower than the .93 estimated by Pope et al. (modified Klinefelter model for 1970, estimation period 1946-1972). The fact that such results appear to depend on the model specification suggests that the exact role of inflation in the determination of land value is unclear.

Finally, by pooling time series and cross section data, our model provides a quantitative measure of the influence of land quality (as measured by CSR) on land prices. This feature, which is not present in the other models just discussed, has potential applications for the valuation of land by appraisers.

Summary

Based on a theoretical formulation of land price formation as an economic rent to a fixed input in a multi-product production system, a single equation econometric model has been specified and estimated to explain land prices in five Iowa crop reporting districts. The data period for estimation was 1967 to 1977. This period was one of major price changes.

This very simple model explained about 99 percent of the variation of land prices within the estimation period. It identified the individual impact on land price of price changes in the three major commodities produced. For example, a 10 percent increase in soybean price corresponds approximately to a 5 to 6 percent increase in land prices in Iowa. The sum of the elasticities with respect to output prices was found to be greater than one. In addition to rising farm commodity prices, technological progress appears to be one of the major causes of rising land prices. Further, land price differences among districts can be largely explained by differences in the "corn suitability rating" estimated by crop and soil scientists. It is found that land prices are a linear homogeneous function of the "corn suitability rating". Thus, a major implication of this work is that an econometric model using a minimum of data may be quite useful for estimating regional and time differences in land values. While far more sophisticated and complex models of land prices could be formulated, both the theoretical underpinnings and the performance of this simple model make it an attractive alternative for further examination. Although formal tests were not conducted on the influence of input prices, urban pressures, or many other possible variables on land prices, the high statistical quality of the estimates and the predictive performance of the model give little reason to suspect that excluded variables have had a strong independent influence on farm land values in this particular market.

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