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## Cross-Sectional Pricing in the Market for Irrigated Land

By Edward F. Renshaw

*This investigation of price-determining influences in the market for irrigated land was motivated originally by a presumption that one way to evaluate land-investment alternatives, such as public expenditures for irrigation, would be to compare the present price of nonirrigated land in the market with an "expected" market price after investments are made. The models were developed to aid in estimating a current market value for land that is comparable, in the value sense, to the price of such land after capital investment. In an attempt to test variants of the theory that a certain proportion of the expected gross receipts is capitalized into land values, that is, that land values can be estimated on the basis of gross farm income, the author has constructed both time-series and cross-sectional models. The time-series portion of the analysis was published in the May 1957 issue of the Journal of Farm Economics (4),<sup>1</sup> "Are Land Prices Too High: A Note on Behavior in the Land Market." The cross-sectional models dealing with this problem are presented here with a unique approach and interesting methodology.*

The approach used in this study to isolate determinants of land price is built on the premise that land value represents a capitalization of expected net income. While net income to land cannot be observed or measured easily owing to joint ownership of agricultural factors of production, gross income, a variable that is closely correlated with net income, can either be measured directly or estimated from acreage response. The models given here are concerned essentially with carrying the weighting principles that underlie

expectation models<sup>2</sup> a few additional steps along the road to empirical application.

### Model 1

Model 1 can be classified as a conventional expectation model; estimated land and water value per acre is related directly to expected crop value per acre, when expected crop value is a weighted function of estimated gross crop value in the 10 preceding years.

<sup>1</sup>Numbers in italics in parenthesis refer to Literature Cited, page 19.

<sup>2</sup>For a more theoretical discussion of the mathematics underlying expectation models readers are referred to a recent article by Marc Nerlove in the *Journal of Farm Economics* (3).

The variables and the estimating equation for model 1 are as follows:

$X_1$  = the per acre value of irrigated land without buildings + the present value per acre of repayment contracts assessed against project construction costs, 34 Bureau of Reclamation projects, 1956.

$X_2$  = expected crop value per acre, 1955.

$$(1.1) \quad X_1 = 117.6 + 1.885X_2 \quad R^2 = 0.59 \quad (.28)$$

The data on project land values were obtained by mailing a return post card to the officers in charge of all irrigation districts having water repayment contracts with the Bureau of Reclamation.<sup>3</sup> The present value per acre was derived by discounting to a 1956 present value the exact or an approximate repayment stream and then dividing by the acreage to which the Bureau was prepared to supply water in 1952. The interest rate used to discount all future repayment streams was 4½ percent, the farm mortgage rate.

Estimated growth crop value per acre in the preceding 10 years<sup>4</sup> is assigned these weights:

$$\begin{array}{lll} X_{1t-1} = 0.2052, & X_{1t-2} = 0.1631, & X_{1t-3} = 0.1296, \\ X_{1t-4} = 0.1030, & X_{1t-5} = 0.0819, & X_{1t-6} = 0.0651, \\ X_{1t-7} = 0.0517, & X_{1t-8} = 0.0411, & X_{1t-9} = 0.0327, \\ X_{1t-10} = 0.0260. \end{array}$$

<sup>3</sup> A distinction should be made between two kinds of sampling error present in the land-value data: (1) Districts reporting may not be representative of the whole project. (2) Errors of enumeration may be present either because project managers have a poor knowledge of land values, or their subjective weighting of productivity differences within the project is incorrect. The 17 included projects with 100 percent of the districts reporting have as a rule only one or two districts, while the 17 projects with only a sampling of districts reporting may have up to 10 or 15 districts reporting. An averaging out of second-class errors could conceivably counterbalance errors of the first kind.

As actual market values that exist during the construction and early development of a given project are likely to be affected by uncertainty as to crop yields after water is applied, by uncertainty as to the repayment responsibility of the water users, and by antispeculation rules adopted by the Bureau in recent years, only projects established before 1950 are used in this paper to estimate functional relations in the irrigated land market.

<sup>4</sup> Source of data: Bureau of Reclamation, *Crop Summary and Related Data, Federal Reclamation Projects* (9) for 1945-54. Crop summary data have not yet been made available for crop year 1955. Ideally, if expected crop value is to represent a refined test of theory, land values also should be those for 1955.

The comparatively low  $R^2$  in equation (1.1) is to be expected in view of the sampling techniques used to obtain both the independent and the dependent data, the broad geographical area over which aggregation takes place (the 34 included projects are rather widely distributed through the 17 Western States), the rather large differences in irrigation enterprises classified by commodity types, the variability in the marginal cost of water to irrigators, and other institutional and technical factors that affect the proportion of total crop income allocated to land and to repayment of irrigation facilities.

From the standpoint of estimating irrigation benefits in terms of increases in land and water values, Model 1 has two serious defects. Crop summary data are not only limited, they also are subject to bias, owing to the fact that the variable repayment contracts that exist between the Bureau and some irrigation districts make water repayment a function of realized crop receipts. Empirical evidence exists<sup>5</sup> to substantiate a belief that these contracts lead to an underreporting of crop yields which in turn causes a downward bias in estimates of crop values. A second defect of model 1 is that it does not permit one to predict land values without information on historical crop returns or a reliable system with which to forecast expected crop values.

For comparison, two additional cross-section models methodologically related to model 1 but not exclusively limited to the pricing of irrigated land have been developed.

### Model 1a

$X_A$  = value of land and buildings per acre, March 1954, by States and for the United States as a whole. Source: *Current Development in the Farm Real Estate Market* (6).

$X_B$  = same as  $X_A$  (Delaware and New England excluded).

<sup>5</sup> A comparison of crop summary data for the North Platte Irrigation Project, 1935-45, with Nebraska Agricultural Statistics for Scotts Bluff County (relatively the most important county within the project) indicates consistently lower yields reported to the Bureau than to the USDA crop reported. Although a comparison of this kind is not conclusive evidence of underreporting associated with variable repayment contracts, nevertheless the magnitudes of the differences are suggestive.



$X_C$ =expected cash receipts from farming + value of home consumption, 1954, where "expected" refers to a weighted function of gross income in the preceding 10 years—divided by the acreage in farms in 1950. Source of data: *Agricultural Statistics* (10).

$$(1a.1) \quad X_A = 25.8 + 1.884X_C \quad R^2 = 0.83 \quad (.12)$$

$$(1a.2) \quad X_B = -1.4 + 3.085X_C \quad R^2 = 0.89 \quad (.17)$$

### Model 1b

$X_D$ =value of land and buildings per acre, 1955, 19 different commercial family-operated farms. Source: *Farm Costs and Returns* (2).

$X_E$ =same as  $X_D$  (Corn Belt cash grain farm and the wheat pea farm excluded).

$X_F$ =expected gross farm income per acre, 1956, where expected income is a function of income in the preceding 10 years.

$$(1a.3) \quad X_D = 15.2 + 2.657X_F \quad R^2 = 0.60 \quad (.53)$$

$$(1a.4) \quad X_E = 10.5 + 2.376X_F \quad R^2 = 0.82 \quad (.12)$$

Model 1b is a severe test of the theory that a constant proportion of expected gross receipts is capitalized into land values by the market. It may be noted that by excluding "cash grain" in the Corn Belt and "wheat pea" in the winter wheat area, two of the most naturally productive agricultural areas in the United States, the coefficient of gross correlation is increased from 0.60 to 0.82. Perhaps equally significant is the tendency for the residuals by type of enterprise to have the same sign. Hope exists for a more perfect aggregation across commodities and regions by weighting expected gross receipts on the basis of differences in climate, soil, markets, and enterprises.

### Index of Gross Crop Value

The development of the second major model in this article involves the crop-index approach to estimation of land values developed in part by H. E. Selby (5).<sup>6</sup> From the standpoint of

<sup>6</sup> By adjusting 1940 census data in a manner similar to the way the 1950 census data are treated here, Selby constructed what he called an index of intensity by arbitrarily assigning the weight of 1.00 to orchards, vine-

predicting changes in land values, the index of gross crop value has two rather attractive properties. First, to the extent that crop summary data are subject to errors in yields reported, a crop-value index may be superior to other estimates of expected crop value in predicting land values, in that random errors in yields reported can be expected to average out because of the effect of the large samples. Further, neither a constant nor a proportional bias in the reporting of yields would affect the ability of the index to predict land values, provided the relative returns expected from different crops are substantially unaffected. Second, the crop-value index itself is a function of cropping response which perhaps can be estimated independently in the case of proposed land improvement more accurately than changes in expected income.

One could build an estimate of expected gross crop returns per acre, commodity by commodity, weighting in some way individual crop values for a period of past years. Provided the differences

yards, planted nut trees, and vegetables, the weight of 0.50 to semi-intensive crops such as sugar beets, cotton, potatoes and beans, and the weight of zero to all other irrigated acreages. No theoretical justification was given for the weights chosen. It should be noted that these weights bear a fairly close relation to the weights obtained from the 1950 crop summary data of the Bureau. Assuming that relative prices have remained roughly the same for most agricultural crops, the similarity in weights perhaps explains the remarkable coefficient of gross correlation of (0.785), which he established between the intensity index and the value of irrigated land without buildings in 199 counties.

By adding alfalfa yield, farm size, and the cost of water, he obtained a multiple correlation coefficient of 0.826. The cost of water had the wrong sign (+), perhaps because of the use of total cost per acre, per year, which may have turned the variable into a productivity index of sorts, if we assume not too great a variance in per unit cost of water.

The Department of Agriculture has developed a productivity index. It is the product of a crop-intensity index, which is a measure of the relative proportion of various kinds of crops grown, and a crop-yield index, which is a measure of relative yields. The chief difference between the USDA productivity index and my crop-value index is the way in which weights are selected and used in constructing the indices. As to the best of my knowledge, the Department of Agriculture has not constructed a productivity index for a cross-section of Bureau projects, no test can be made of the relation between land values and the productivity index. A discussion of the productivity index may be found in the following citations: (1), (8).

in receipts by crops are not so large as to affect materially the accuracy of prediction, commodities can be grouped together. If expected receipts per acre by commodity group do not vary unduly among farms, communities, or projects, higher order averages can be substituted for more local averages—the extreme case being to weight local acreage according to expected national crop-value averages. I shall call this an index of gross crop values per acre.

In order to establish a severe test of the aggregation hypothesis underlying the crop-value index, acreages of various crops grown under irrigation were grouped into the following categories and assigned weights derived from crop summary data on Federal reclamation projects:

1. Cereals .....	17.5
2. Seeds .....	37.3
4. Miscellaneous .....	49.8
4. Vegetables and truck .....	66.5
5. Hay and forage .....	9.4
6. Fruits and nuts .....	100.0

Weights were calculated for each group on the basis of a 3-year average weighted crop value per acre devoted to each commodity group for all reclamation projects. The group (fruit and nuts) with the highest 3-year average crop value per acre was arbitrarily assigned the weight of 100 and the other groups were indexed accordingly.

Individual project, country, or district acreages of commodity groups were multiplied by the group weights derived from the crop summary data, summed, and divided by the total area irrigated to get an index value for each observation. As duplicate acreage (resulting when more than one crop is grown on the same ground) is excluded only from the total area irrigated, in theory the index values could range from 9.4 to something over 100.

A direct test of the aggregation hypothesis underlying the crop-value index can be made by correlating the index directly with expected crop value (variable  $X_2$ , model 1). As one would suspect, the resulting correlation coefficient is higher than either of the coefficients associated with correlating directly and separately the two independent measures of gross crop value with land and water value.

## Model 2

Preliminary results of the test of the hypothesis that the crop-value index is a good measure of

land value are summarized in the equations of model 2.

$X_3$ =postal survey estimate of the value of irrigated land without buildings 5 years ago, plus the present value of water-repayment contracts, 30 Bureau of Reclamation projects.<sup>7</sup>

$X_4$ =estimated value of irrigated land without buildings, 46 counties in which the proportion of irrigated land within wholly irrigated farms was 50 percent or more, 1950 census.<sup>8</sup>

$X_5$ =value of irrigated land, 37 irrigation enterprise organizations, 1946 (all enterprises having a substantial acreage of cotton and citrus excluded). Data were taken from the original questionnaires of a survey study of irrigation-enterprise organizations conducted by the former Bureau of Agricultural Economics and the Soil Conservation Service in 1946.

<sup>7</sup> Four projects—Carlsbad, Balmorhea, Austin, and Rio Grande, all in the Southern Plains—were excluded because cotton, a principal crop in the miscellaneous category, was inappropriately indexed. As cotton is listed in the crop summary tables under lint and seed, cotton acreage was given inadvertently a double weight. Further, nonprice rationing of water on some projects makes the yield variability between projects excessive.

<sup>8</sup> The 1950 Census of Irrigation (7) has sample estimates of the value of land and buildings per acre by counties for farms classified as wholly irrigated. (Wholly irrigated farms are farms that reported 1 acre or more of cropland harvested in 1949 and on which all of the cropland harvested was irrigated. All, part, or none of the other land in the farm may have been irrigated.) A difficulty associated with using these estimates arises in subtracting out the value of nonirrigated land within farms classed as wholly irrigated. The value of nonirrigated land in wholly irrigated farms does not appear to bear a simple relation to the value of nonirrigated land in farms classified as nonirrigated. (Nonirrigated farms include all farms with less than 1 acre irrigated in 1949.) Places containing 3 or more acres that produced agricultural products valued at \$150 or more in 1949, and places containing less than 3 acres with sales of agricultural products of \$150 or more in 1949 are counted as farms.

To some extent, bias in census estimates of irrigated land values can be minimized by selecting counties with a high proportion of irrigated land within wholly irrigated farms. Unfortunately, the number of reclamation projects located in counties in which the proportion of irrigated land in wholly irrigated farms exceeds, say, 50 percent, is very small.



$X_6$ =crop-value index described above (based on acreage weights for commodity groups taken from the crop summary data of the Bureau of Reclamation 1948-50).

$X_7$ =crop-value index. Not comparable to  $X_6$  for these reasons: Citrus is an important crop in a number of census counties and is of only negligible importance on projects of the Bureau from which the acreage weights were taken. No acreage duplication exists as weighted crop acreage was divided by the sum of unweighted crop acreage. The index assumed that all vegetables were grown on farms classified as wholly irrigated (and that none were grown on farms classified as partially irrigated). These three factors tend to make crop-value index parameter estimate much larger in equation (2.2).

$$(2.1) \quad X_3 = 24.9 + 0.805X_6 \quad R^2 = 0.66 \\ (0.11)$$

$$(2.2) \quad X_4 = -104.9 + 1.901X_7 \quad R^2 = 0.74 \\ (0.15)$$

$$(2.3) \quad X_5 = 28.7 + 1.197X_6 \quad R^2 = 0.86 \\ (0.082)$$

In analyzing the results of model 2, the crudity of the crop-value index actually constructed should be emphasized. In it, such pairs of commodities as corn and rye, apples and peaches, alfalfa and straw, and cotton and dry beans were given equal weights when, in fact, the expected crop value per acre of the first is often twice that of the second. Our theory would suggest that the ability of the index of crop value to predict could be improved by refining the crop weights in such a way that aggregation takes place across fewer commodities. In addition to refining crop weights, the variance explained, particularly in equation (2.1) and (2.2), might be increased with better estimates of irrigated land values. Better data could easily be acquired by altering the census questionnaire or by including questions on land values in the crop summary questionnaire of the Bureau of Reclamation.

With respect to the individual regressions, it should be pointed out that the assumptions underlying equation (2.1) and (2.3) are most comparable. The higher  $R^2$  in equation (2.3) may be deceptive in part owing to a larger range in data. For example, if the four California and Arizona

projects (Yuma, All American Canal, Gila, and Salt River) are left out of the equation (2.1), resulting  $R^2$  is lowered to 0.36. However, it may be indicative of better dependent variable data and a loss of important information through aggregation over irrigation districts to the project level. The high  $R^2$  must surely indicate considerable stability in relative agricultural prices between 1946, the date of the land-value estimates, and 1950, the year for which our acreage weights are assumed to have the greatest relevance.

Having arrived in a somewhat devious way at the hypothesis that land and water value is, in effect, some weighted function of the proportion of total acreage devoted to various crops, the natural suggestion would be to run a direct multiple correlation between land value and crop percentages. The chief advantage of this correlation is that, knowing only the acreage distribution of various crops, one can obtain acreage weights directly from the data. One need not know a great deal about actual gross crop values. Aggregation across commodities should of course be improved by knowledge of relative crop values per acre.

As a preliminary test of the hypothesis that acreage response is a good predictor of land value, I have developed a simplified equation using the basic data from which equation (2.3) was obtained. The results are summarized in model 3.

### Model 3

$X_8$ =the percentage of total irrigated acreage devoted to cereals.

$X_9$ =the percentage of total irrigated acreage devoted to seeds, miscellaneous, and vegetables and truck.

$X_{10}$ =the percentage of total irrigated acreage devoted to fruits and nuts.

$$(3.1) \quad X_5 = 101 + 0.459X_8 + 2.611X_9 + 10.41X_{10} \quad R^2 = 0.88 \\ (1.01) \quad (1.32) \quad (0.92)$$

The commodity group that was left out of model 3 in order to obtain parameter estimates is hay and forage. Despite additional aggregation across commodity groups (three commodity groups—seeds, miscellaneous, and vegetables and truck—were collapsed into variable  $X_9$ ) the coefficient of gross correlation is slightly higher for equation (3.1) than for equation (2.3).

A limitation to the technique suggested in model 3 is the fact that computing effort is a rapidly increasing function of the number of crop percentages included in the model. The problem of too many independent variables can be overcome to some extent by a high degree of aggregation, as I have done in model 3, or by classifying data according to enterprise, regional, or other differences and running separate regressions containing fewer variables.

One might, on other grounds, wish to classify the basic data and run separate regressions in order to test the stability of parameter estimates and to catch the effects of other factors believed to influence cross-sectional land values. In the case of irrigated land, it would seem desirable to classify the data according to climatic regions and water-right differences in the hope of isolating the effects of nonprice rationing of water and variability yield. A classification according to enterprise differences might be justified in order to catch differences among enterprise types with respect to the allocation of factor income. Any differences between crops in the proportion of per acre crop value that is net income to land will of course be picked up directly in the regression on individual crop percentages.

### Evaluation of the Crop-Value Index as a Predictor of Land Value

For the principle of the crop-value index to be a success as a predictor of land value, the cropping pattern must be directly related to those economic, technological, and physical factors that govern the marginal product of land. It would be a fallacy to presuppose that cropping pattern itself determined land value, as the obvious conclusion would be to put all irrigated land into fruits and nuts. To the extent that the underlying factors governing productivity, such as type of soil, climate, topography, distance from market, local demand, water rights, and the expected cost of water, are directly related to, or im-

pose restraints on, a rational cropping pattern, many variables that influence land value can be collapsed into statistics on the acreage devoted to various crops. Essentially, all that a crop-value index can do is to measure the effect on land value of substitutions to crops yielding higher opportunity returns per acre. It will be of little use as a predictor of land value if the real factors that affect land value either are not, or cannot easily be made, a function of cropping pattern by defining crops appropriately in such a way as to pick up differences in income-yielding potentiality.

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