Budgeting Techniques in Estimating Farm Adjustments and Marginal Returns

By Earl O. Heady and Ross V. Baumann

Prediction in production economics helps individuals and groups to make choices among the uses of resources. Prediction is usually made by using a sample drawn from a population in which the variables, quantities, or parameters to be estimated are already in existence. But in many situations with which biological and economic research workers deal, the parameters they want to predict are not found in an existing population because farmers have not yet used the recommended production techniques. They therefore frequently must formulate predictions either by inference from a sample that is assumed to represent a population, or by budgeting procedures. Conventional budgeting procedures frequently have limited usefulness because the empirical data are assumed to be discrete, linear, and without error. This article brings out some refinements in conventional budgeting procedure. These suggested modifications are believed to increase the information that can be gained from a small number of budgets, and to give greater knowledge of the predictional error involved.

ADJUSTMENTS IN FARMING, as in the change to soil-conservation systems of farming, may involve many changes in enterprise combinations and production practices. A conventional research procedure often used to test the validity of such a change is to construct a single budget for each of several alternative systems for a few so-called typical farms, and then handle each as a case study. Rather frequently, the budgets compare only the usual with the optimum in physical adjustments.

At least two assumptions underlie this typical budgeting procedure: First, that the population for which the budgets serve as an inference has a zero variance; and second, that the degrees in the adjustments are discrete and the relationships are linear. The assumption of linearity is the same as in the analytical procedure known as linear programming.[1] The treatment of variance is also similar in the two procedures.

The group of functional relationships might be presented in a single functional relationship. If we could synthesize the fixed and variable costs for a farm, we could express the total, average, and marginal cost functions as algebraic equations, and thus predict all points on the relevant curve.[2] This system provides a somewhat different form of estimate from a similar prediction of the same parameter based on a sample. This is particularly so if the prediction refers to a statement of probability. However, the one set of calculations that specify the nature of the fixed costs—the short-run production function or input-output ratio—and the prices of varying resources allow estimates at many points over a wide range of the relevant (independent) variable.

This method would become cumbersome because adjustments in the entire system of farming involve so many more variables and functional relationships than a simple cost function. Consequently, we have preferred instead to use refinements in budgeting procedures that allow some relaxation of the assumptions of zero variance for the population, discrete data, and linear relationships. In addition, our refinements permit the use of standard statistical procedures even though many research workers look upon budgeting as a nonstatistical technique. In the following paragraphs some of these procedures are outlined as we have applied them in research

[1] Cf. KOOPMANS, T. C., EDITOR. ACTIVITY ANALYSIS OF PRODUCTION AND ALLOCATION. New York, Wiley, 1951.

[2] Cf. HENRY, W. F., BRESSLER, R. G., JR., and FRICK, G. E. EFFICIENCY OF MILK MARKETING IN CONNECTICUT: 11. ECONOMIES OF SCALE IN SPECIALIZED PASTEURIZING AND BOTTLING PLANTS. Conn. (Storrs) Agr. Expt. Sta. Bul. 259, 1948.

studies. Our examples are drawn from a study of the economics of soil conservation.

Optional Budgeting Techniques

Our first refinement was to draw a sample that represented a homogeneous producing situation. Instead of studying a heterogeneous soil area in which the quantities and relationships estimated would be hybrids or averages representing the situation of no single farm, we selected a random sample of farms, all of which had essentially the same quantities and combinations of soils. A sample was drawn in the Marshall soil area of Iowa.[3] The sample included only farms of the most numerous size, that is, 160 acres.

Although there was great heterogeneity of soils in the areas, pre-established limits in respect to types and proportional acreages of soils were maintained in the samples used for study by selecting from a larger group of farms for which agronomists had made soil maps. The relevant population of farms was stratified on the basis of the degree of soil conservation before making the random selection from the field records of the county assessor. Data in table 1 for high- and low-conservation farms indicate the homogeneity of one sample.

Estimation of Relationships

Because soil conservation is not a discrete phenomenon—it can be attained in different degrees and a farm can move from one to other levels of erosion control—we constructed budgets for farms with similar resources which had various degrees of conservation attainment, and then employed regression analysis. This procedure eliminates the necessary assumptions of discrete alternatives and linear relationships.

More specifically, rather than construct budgets representing conservation and usual systems of farming for a typical farm, we computed conservation systems for 30 farms on Marshall soils that had already attained different levels of conservation. As a matter of convenience and practicability, soil loss in tons per acre a year was computed, both for present farming systems and recommended farming systems.

TABLE 1.—*Mean acreage per farm of specified soil types for high- and low-conservation farms*

Conservation	Acreage of specified soils				Total excluding roads
	Bottomland soils	Marshall silt loam: Less than 4-percent slope	Marshall silt loam: 4-percent slope or over	Shelby silt loam	
	Acres	*Acres*	*Acres*	*Acres*	*Acres*
High conservation.	24.9	35.0	90.8	4.9	157.1
Low conservation.	25.3	39.4	86.3	9.9	158.5

Heady and Allen, ibid.

After budgets were constructed for conservation adjustment, regression analysis was used to predict changes in returns, costs, and resource requirements for a single farm as it adjusted to different conservation levels. (This analysis was also made for several farms differing in existing levels of attainment as they adjusted to a given level of soil conservation.) Each budget was treated as an observation and the statistical analysis was carried forward accordingly. Regression curves, such as the ones presented in figure 1, were the result in the Marshall soil study.

Thus, rather than compute a budget representing the income, for example, for each point along the current conservation scale—the horizontal axis in figure 1—we were able to estimate an infinite number of budgets by the application of regression analysis to our budgets for 30 farms. The income figures estimate the addition to returns that would be forthcoming if farms of different levels of conservation attainment were to adjust to a specified goal, roughly a soil loss of 6 to 7 tons an acre a year.

This is in contrast to the conventional procedure of using a case-study budget, or of averaging several budgets into a mean prediction in which the estimate applies only to farm-

[3] The results of the application of the methods here outlined as a part of the study in the Marshall soils area are reported by Heady and Allen, in RETURNS FROM AND CAPITAL REQUIRED FOR SOIL CONSERVATION FARMING SYSTEMS. Iowa Agr. Expt. Sta. Research Bul. 381. Further results from this study and from one in the Ida-Monona soils area are expected to be available in the near future.

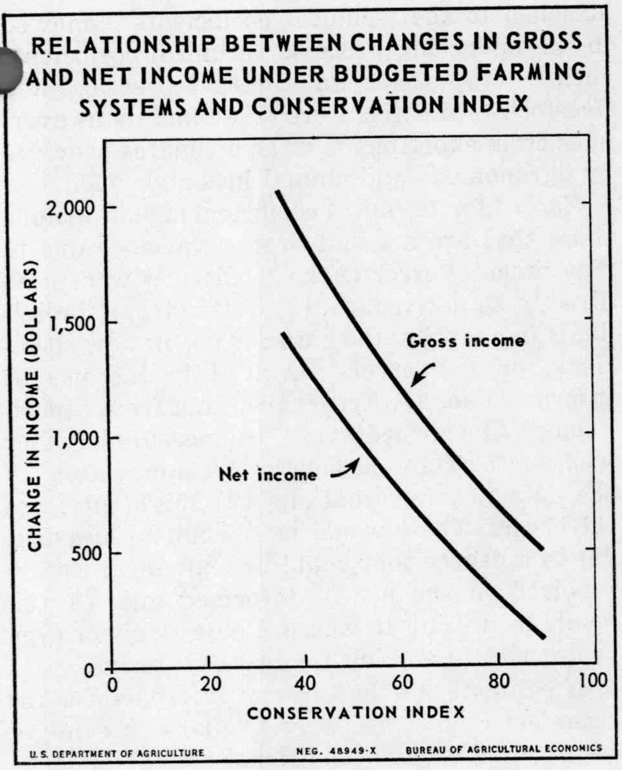

FIGURE 1

ers whose situations were characterized by the mean condition.

In addition to making it possible for us to estimate the results for a large number of budgets without the labor of actually constructing all of them, our procedure also allowed us to test the hypothesis of linear against curvilinear relationships, or constant against increasing or decreasing productivity of resources. In the example cited in figure 1, the regression coefficient for the squared term was significant at the 5-percent level of probability. We therefore accepted the hypothesis of a nonlinear relationship.

If our relationships were linear and our population had a zero variance—implicit assumptions that are usual in budgeting—the procedure could be simplified even more. We could have constructed two budgets, one at each extreme of our observations, and predicted all of the budgets in between as points on our straight line or linear relationship.

Estimational Errors

Furthermore, in our procedure we are able to specify a probability range that is due to variance in the characteristics of the farms in our sample. To illustrate this possibility, let us examine our estimates of the marginal value returns from capital invested in soil conservation for 12 farms with an annual estimated soil loss of 40 to 50 tons an acre a year. (The capital requirements would be rather large for any changes to accomplish more conservation.) These estimates are based on a number of alternative budgets for each farm, with a regression equation used to estimate the total returns function as varying quantities of capital are invested in soil-conservation adjustments.

Total returns attributed to conservation investment are related to capital invested in soil conservation and related farm adjustments. Total capital includes the cost of soil conservation practices, annual cropping practices, livestock, livestock equipment, purchased feed, the value of labor beyond 15 man-months a farm, fuel and machinery, and miscellaneous costs, although the annual outlay for some of these items would entail an investment of less than a year.

Equation 1 below shows the computed regression equation relating total returns (I_m) from conservation (beyond that currently attained) to total capital investment. Equations 2 and 3 show the returns at the upper (I_u) and lower (I_l) fiducial limits at a 5-percent level of probability for each regression coefficient:

$$I_m = 0.693 + 36.513C - 0.00272C^2 \quad (1)$$
$$I_u = 0.693 + 41.515C - 0.00302C^2 \quad (2)$$
$$I_l = 0.693 + 31.511C - 0.00242C^2 \quad (3)$$

From these data we are able to estimate the total return from various amounts of capital that are included in our range without constructing a like number of budgets. We also can specify the equations (by computing the derivatives of the three equations above) indicating the marginal returns (MR) per dollar of capital. These are given in equations 4, 5, and 6 for the mean, upper, and lower limits, respectively:

$$MR_m = 36.513 - 0.00544C \quad (4)$$
$$MR_u = 41.515 - 0.00604C \quad (5)$$
$$MR_l = 31.511 - 0.00484C \quad (6)$$

Using these data to estimate the marginal returns per dollar when $2,000 and $4,000 are invested in conservation farming systems, we obtain the figures for marginal returns in cents (table 2).[4] We can show the added return per dollar of capital in many different quantities. We do not have to make out 6,000 budgets to estimate returns on capital ranging from $1 to $6,000.

TABLE 2.—*Marginal returns from capital invested in soil conservation on Marshall soils, 1945 prices*

Item	Marginal returns per dollar with additional capital investment of	
	$2,000	$4,000
	Cents	*Cents*
Mean	25.63	14.75
Upper limit	29.44	17.36
Lower limit	21.83	10.15

We are also able to specify a probability range, rather than present our data as the given figures, that is, estimates without variance, as is the common procedure in budgeting. Even at the lower limits, capital invested in conservation farming systems appears profitable, and confidence in our estimates is accordingly increased. Although conservation can be attained in varying degree, numerous practices are discrete. Our procedure gives us some confidence that conservation investment on this particular group of farms is profitable within a reasonable range of capital.

Limitations and Other Problems in Estimation

The ranges of error or fiducial limits that relate to the estimates do not take into account differences occasioned by year-to-year variations in weather and prices. The sample was taken in 1946 and yields were based on 10-year averages.

Neither do they take into account any error attached to the technical coefficients employed in the budgeting process. Technical coefficients such as crop yields for different practices and livestock-feed ratios were taken mainly as averages from experiments or as estimates provided by agronomists and animal husbandrymen.

Errors for technical coefficients could include those that are a result of (1) variance due to experimental error if the coefficients were used directly as derived, or (2) estimates of individuals in adapting the data for use in new situations, or (3) errors involved in the use of informed guesses. Errors resulting from experiments (1) can ordinarily be measured rather well statistically although the application of the data in new situations (2) might increase the errors. These would be difficult to measure, yet to a degree they could be explained. Errors involved in the use of informed guesses (3) would be difficult to measure objectively or even to describe in any but the broadest terms.

If estimates of the error of inference for the technical coefficients were available, we might have computed two additional sets of budgets, using the technical coefficients set at the 5-percent fiducial limits. The process itself, however, might involve several unanswered questions as: Are the several error quantities additive or must they be compounded? Should the functions fitted include the mean estimate based on average coefficients, the upper limit of the functions estimated with technical coefficients at the upper limit of the fiducial range, or the lower limit of the functions estimated with technical coefficients at the lower limit of the fiducial range, that is, the fiducial range for the technical coefficients themselves?[5]

But we believe that, aside from the common reservations which can be applied to the budgeting technique, not discussed here, our refinements represent an improvement on those procedures which assume budget data to be entirely discrete, linear, and without error of any nature.

[4] Marginal returns on capital are high on this particular sample of farms because their cropping systems are poor, they have little livestock, and they do not use their labor fully. Some individual capital items, such as seed for legumes, which might serve in a complementary capacity to grains, actually will return several hundred percent on the investment.

[5] Our estimates, like many others, do not include analysis of the time components of income and investment; neither do they adequately account for managerial differences and the capital-uncertainty complex.