Predicting Farm Organization With Maximum-Profit Linear Programming Models

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PREDICTING FARM ORGANIZATION WITH
MAXIMUM-PROFIT LINEAR PROGRAMMING MODELS

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SUMMARY

The purpose of this study was to investigate factors which may limit linear programming as a predictive tool in agricultural supply response studies. It has specifically centered attention on components of maximum-profit linear programming models and characteristics of farm operators which create differences between actual and linear programmed farm organizations.

Twenty farms in Wasco County, Oregon, were selected for the empirical investigation. Data on enterprise costs, technical coefficients, and restraints were obtained from each farmer selected. Additional information on age, education, farming experience, family size, and income were also obtained for each farmer.

Three general programming models were constructed for each farm. Model I represented year-to-year choices among alternative levels of participation in government wheat and feed grain programs. Separate submodels were developed for each of the years from 1963 to 1966, which represented participation alternatives in wheat and feed grain programs in these four years. The purpose of Model I was to calculate profit-maximizing solutions for individual farms in this short-run context, to make comparisons with actual decisions of the farmers within the same framework, and to isolate factors which created differences between actual and programmed solutions.

Model II was constructed to predict individual farm organization where the planning horizon was sufficiently long for changes to occur in resource use patterns and enterprise combinations. Land, family labor, and in some cases operating capital, were treated as fixed resources. The objectives of the Model II analysis were to evaluate the degree of association between the actual and profit-maximizing programmed farm organizations and to determine factors which caused differences between the two solutions.

Model III was the same as Model II except that its objective function required the least-cost organization for obtaining a given level of income. Its purpose was to provide an alternative representation of the objectives which guided the farmers in their management decisions.

The Model I analysis indicated that farmers had difficulty making profit-maximizing decisions with respect to choices of government programs. The main factors which hindered them were continual changes in programs and associated incentives, and inability to individually assess the economic consequences of alternative levels of program participation.

To facilitate a comparison between the actual and calculated farm organizations in the Model II analysis, a set of indices was developed. These indices made it possible to compare the two organizations in terms of labor and land use patterns and enterprise combination.

The Model II analysis indicated that maximum-profit models did not accurately predict the decisions of farmers. However, they did perform better in the short run than in the longer run situations. They also predicted production for major enterprises better than for supplementary enterprises.

Model III, with its minimum-cost objective function, described labor use patterns on 10 farms, land use patterns on 15 farms, and enterprise combination on 18 farms as well or better than did Model II with its maximum-profit objective function.

For this study, expected yields were the normal yields for the farms. In most cases they had been proven according to Agricultural Stabilization and Conservation Service requirements. Expected prices were 10-year averages for each commodity. Sensitivity analysis on a sample of the farms indicated that large changes could occur in price expectations and not affect the solutions for Model II.

Errors in specification of enterprises to include in the models were a major source of differences between actual and programmed organization. Enterprises must not only be physically and economically feasible, but also psychologically acceptable to the farmer.

Characteristics such as education, family size, age, and experience were found to be associated with the farmer's management objectives.

INTRODUCTION

In a dynamic economy such as that of the United States, effective decision making in the agricultural sector, whether at the individual farm level or in the aggregate, is greatly facilitated when economists are able to make reliable predictions (*17*).[1]

One type of information which has been in wide demand is estimates of aggregate supply response and individual farm adjustments to expected changes in the economic environment (*7*, pp. 3-4).

Analytical tools traditionally used to derive information of this nature have been related to regression procedures. However, these procedures have exhibited weaknesses in terms of methodology and data (*1*). Economists working with regression and econometrics have had difficulties incorporating into models conditions such as uncertainty, capital rationing, technological change, and nonmonetary goals, all of which influence the accuracy of the resulting predictions (*7*, pp. 14-24). Due to limitations in data required for studies at the micro-level, these methods are generally limited to aggregate analyses.

An alternative approach which has found wide acceptance among economists is linear programming. Its main appeal is that it frees the researcher from some of the restrictions under which he operated when using regression or econometrics (*10*, pp. 470-471). With linear programming, the analysis can be conducted at the farm level and the results aggregated on an area or regional basis. Forces which cause changes in the variables under observation, such as factors of production or enterprise interrelationships, can be studied in detail (*16*, p. 165). In making predictions of adjustments, the expected impact of technology, capital rationing, and other factors difficult to account for in traditional methods, can be incorporated into the models (*27*, pp. 11-18).

Because of the apparent advantages of this approach and current pressures for information of a predictive nature, this procedure has provided the framework for a large number of studies concerning supply response and farm adjustments. Some of these studies are listed in the bibliography (*5*,*6*,*11*,*25*,*26*).

Linear Programmed Supply Response and Farm Adjustments Analysis

Linear programming is a particularly attractive tool to researchers

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[1] Italicized numbers in parentheses refer to Literature Cited on page 31.

engaged in supply response and adjustment studies, since it allows them to accomplish two objectives at the same time. First, they are able to estimate aggregate commodity supply response, and second, they gain information on individual farm adjustment potentials (*2*). This is achieved by basing the analysis on representative farms. A common procedure followed in these studies is to:

1. Stratify the region into areas based upon type of farming or other relevant characteristics such that the farms within the area might be expected to have similar yield potentials, prices, and costs.

2. Sample each area to provide a basis for sorting farms into homogeneous groups based upon size, soil type, or other relevant factors.

3. Combine data from secondary sources with information obtained from the sample to construct representative farm linear programming models and estimate individual supply functions (*1*).

There are three general sources of error in this procedure. First, errors due to aggregation which arise when a limited number of representative farms is used to describe a whole population. This has been designated as "aggregation bias" (*4*). The second source of error is in the data. Coefficients are taken from sample surveys and from secondary sources, both of which are subject to error. The third major source of error occurs when the number and kind of equations in the model do not accurately reflect all of the critical physical and economic relationships in the environment they are attempting to describe. This frequently is referred to as "specification error" (*19*).

Considerable research effort has been expended in developing procedures for measuring and reducing aggregation bias (*22*) and there are continuous studies for improving the data.[2] Errors which occur as a result of performing the analysis within a linear programming framework have received little explicit attention. This, however, is not because of a lack of awareness of the problem. Some researchers consider this to be a major source of error in using the linear programmed representative farm approach to supply analysis (*21*,*24*). The content of this study centers attention on specification error in maximum-profit linear programming models.

Conditions for Accurate Prediction

This section outlines conditions under which a single farm programming model would result in a solution predictive of the decisions a farmer would actually make within the limitations of his farming operation. These conditions are as follows:

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[2] Many of these studies are organized and coordinated through regional research groups, such as the W-54, GP-5, and S-42 committees.

1. The model would include coefficients which accurately reflect the restraints within which the farmer operates.

2. Technical coefficients in the body of the matrix would accurately relate all physically, economically, and psychologically feasible enterprises to the appropriate restraints.

3. The coefficients in the objective function would accurately reflect the farmer's expected values for these constraints.

4. The objective function in the model would accurately describe the objectives which guide the farmer in his decision-making processes.

5. The farmer would be consistent in adjusting his farm organization in accordance with his objectives, and these objectives would not change over time.

The first four conditions require that the model be constructed accurately, while the last condition requires that the farmer be consistent in choosing his objectives and act in accordance with them. This last condition becomes particularly important as the time horizon becomes longer. If the purpose of the analysis were to predict farm organization in five years under a given set of prices and technology, it would be necessary to assume a particular objective function. If the farmer's objectives should change during this time, or he should fail to act in accordance with his objective function, the prediction would be incorrect.

It is possible that all of these conditions could be fulfilled in constructing a programming model, and that thereby an accurate prediction of a farmer's actions under a given set of circumstances could be made. However, the time factor could become very important. The least amount of error would occur if the objective were to construct a model predictive of a farmer's current actions. All pertinent data could be gathered by direct measurement and through conferences with the farmer.

As the target date for the prediction is pushed into the future, chances for error increase. Not only are all coefficients estimates subject to error, but expectations and objectives must also be estimated.

Purpose of the Study

The purpose of this study was to investigate factors which create differences between the actual response of farmers to their economic environment as reflected in their farm organizations, and the predicted response obtained through maximum-profit linear programming models of the farms. Such an analysis should provide insight into the causes of specification error in linear programmed supply response analyses.

METHOD OF ANALYSIS

Twenty farm units were selected for the study. All of the farms were located in Wasco County, Oregon, where small grains and livestock are the major farm enterprises. Physical and economic data were gathered from each participant so that programming models could be constructed which would represent as closely as possible his particular management ability and the productivity of his resources in their alternative uses. Personal information was also recorded with regard to age, education, experience, size of family, and financial condition.

Linear programming models were developed for two decision-making situations. Model I described year-to-year choices among alternative levels of participation in government wheat and feed grain programs. Model II and Model III considered a planning horizon which allowed a re-combination of enterprises and changes in resource allocation.

The analysis of factors which created differences between the actual choice of participation in government programs and that specified by Model I was conducted on the assumption that profit maximization was, in reality, the objective of the farmers, and that there were no other specification errors in the models. It also assumed that input data were accurate.

The Model II analysis assumed that differences between actual and programmed farm organization could be attributed to errors in specification of the model. It was hypothesized that major sources of specification error would be in the selection of enterprise alternatives and in the choice of the objective function.

The actual organization for the Model II analysis was defined as the average for each farm over the four years from 1963 to 1966. Where a major change had occurred in enterprise combination or resource use during that period, current organization was based on the average after the change occurred.

Model III was constructed to test the hypothesis that another type of objective function would represent farmers' actual objectives as good or better than a profit-maximizing objective function. The least-cost criterion was selected for this purpose.

Indices were developed to measure the degree of association between the actual farm organization and solutions calculated through Model II and Model III.

Regression procedures provided a means for establishing relationships among characteristics of the farmers and differences between actual and programmed farm organizations.

Model I

The purpose of Model I was to calculate profit-maximizing solutions for individual farms in a short-run context, where participation in government programs was the only decision required to make comparisons with actual decisions of farmers within the same framework. It was also formulated to isolate factors which contributed to differences arising between the actual and programmed organization. Separate models were developed for each of the years 1963 to 1966, to represent the alternative choices among wheat and feed grain programs open to the farmers.

Restrictions built into the model were, land of various levels of productivity available for crops in the particular year, the wheat allotment, and the barley base. A set of institutional restraints was included to limit production in accordance with the program alternatives. Activities were provided which represented all choices in both wheat and feed grain programs.

Participation involved discrete choices which could not be handled by a single programming solution. This made it necessary to re-run the model for each farm enough times, with the appropriate variables excluded, to create solutions for each of the discrete choices. From among these solutions, the profit-maximizing program combination was established by considering the value of the objective functions.

The same technical coefficients and costs were used for all four years. These data represented typical input requirements and production for the individual farms. Government price support and diversion payments were the actual rates which the farmers could receive in each year. Product prices for each of the four years were averages for the months from August to May, and represented the farmers' price expectations for each of these years.

Model II

The structure of Model II was developed to predict the organization on the individual farms within a relatively long-run context. Assumptions made in constructing the models which received special attention in the analysis are as follows:

1. Expected prices were 10-year averages at the local market; expected costs were those currently paid by the farmer.

2. Expected yields were those established by the Agricultural Stabilization and Conservation Service. In most cases they had been proven on the basis of three years' production.

3. All farmers were strict profit maximizers within the framework of the activities and restraints used for the particular farm.

4. Enterprises physically and economically adapted to the area were acceptable alternatives for all of the farmers.

5. All significant physical and institutional restraints were specified in the models.

Factors restricting resources were cropland, range, the wheat allotment, family labor, full-time hired labor, and operating capital. It was assumed that, in the absence of land purchases, investment capital was not a critical resource. Operating capital was limited on only part of the farms.

Equations and variables included to describe the nature of operating-capital restrictions were based on an approach suggested by Rogers (*18*). This assumed that the anticipation of production created sufficient credit to cover all cash costs of production for enterprises established on the farm, with the exception of feed and livestock purchases for hog operations or cattle feedlots. However, it also assumed that where a farmer could provide feed, credit was available for livestock purchases and operating costs for a feedlot. Alternatively, if the farmer provided the livestock, credit was established for feed purchases and cash operating costs.

Labor restrictions were incorporated to limit quality as well as quantity of each labor restraint. Overhead labor was subtracted in calculating the quantity available for enterprises in each period. For a few farms, labor hiring was limited to some maximum level, even though plenty of hired labor was available. This helped maintain the proper mix between skilled operator labor and full-time and seasonal hired labor. Most farmers restricted hired labor to field work, feeding the cow herd in the winter, and to maintaining equipment, fences, and buildings. Work such as seeding and harvesting crops, calving, or handling a feedlot was done either by the operator himself, or under his close supervision; therefore, only limited amounts of hired labor could be used.

Enterprise alternatives included wheat, barley, grain hay, alfalfa hay, and improved pasture on dry cropland, while irrigated land had these alternatives plus corn silage for two farms. Livestock enterprises consisted of beef cows, brood sows, cattle feedlots, and a program of grass fattening. Calves produced on the farm could be sold as weaners, wintered and put in the feedlot, or grass-fattened where irrigated pasture existed. Also, feeder cattle could be purchased as calves or yearlings for the feedlot or for grass fattening. The feedlot was assumed to be fully automated.

The brood sow enterprise was set up on the assumption that two litters would be produced per year and fattening would be done in confinement.

Crop rotations on irrigated land were calculated within the linear programming model. The procedure for incorporating rotations was patterned after that used in the "National Model" of the United States Department of Agriculture (*20*). This allowed the optimum rotation to be specified in the solution in a manner that interaction between crops in various sequences was accounted for. Traditionally, several rotations would have been established prior to programming, and included in the model as separate activities. This approach would arrive at the most profitable rotation among those constructed, but there was no assurance that the optimum rotation would be included in the set of alternatives. The approach used in Model II made the rotation dependent on economic conditions as well as physical and biological interrelationships.

Much of the input data for Model II was obtained from the farmers and represents input requirements for the particular farm under average conditions. Enterprise coefficients for dryland wheat, barley, grain hay, and alfalfa were calculated for each farm separately. The same was true for beef cow enterprises. Farm and secondary data were used to construct budgets for the remaining enterprises.

Product prices used to represent the expected prices of the farmers were 10-year averages for each product, which included the years from 1956 to 1965.

Like the short-run analysis, a step-wise procedure for including and excluding variables was used to obtain a series of solutions for each farm. With this procedure, the objective function could be evaluated for several enterprise combinations.

Model III

Model III was identical to Model II except for two equations. The objective function in Model II was altered to reflect that of a least-cost model by eliminating all positive coefficients in the equation. An additional equation was added to restrict the solution to the income level desired for the particular farm. With the exception of the right-hand side, which contained the level of income, this equation was identical with the objective function equation in Model II. Since the coefficients in the new objective function were negative, a maximizing routine was used in solving the equations.

The income level for each farm in the least-cost model was defined in the same manner as total net revenue in the maximizing model. Therefore, it was composed of gross revenue minus variable costs of production. The income figures were established through consultation with the individual farmers and represented long-run estimates.

MODEL I RESULTS

Model I was used to calculate profit-maximizing choices among government wheat and feed grain programs. With 20 farms and four years of data for each farm, there was a total of 80 observations to appraise with respect to program choices.

Two levels of choice were considered. First, farmers were required to choose between compliance or noncompliance with wheat and feed grain programs; and second, if they elected to comply, then a choice of level of participation within the program selected was required.

There were four alternative combinations of compliance to consider:

1. Participation in both wheat and feed grain programs.

2. Participation in the wheat program but not in the feed grain program.

3. No participation in either program.

4. Participation in the feed grain program but not in the wheat program.

Possible levels of participation within wheat and feed grain programs varied over the four years included in the study. For 1963 and 1964 the choice was to decide whether or not to divert additional acres of wheat allotment or barley base. Programs in 1965 and 1966 were more complicated, since a substitution of one crop for another was also possible when compliance with both programs was selected.

In view of the two general levels of choice, first selecting a combination of wheat and feed grain programs, and then choosing a level of participation within the programs selected, there were three possibilities for optimality: first, the optimum combination of programs; second, the optimum level of participation within the optimum combination of programs; and third, the possibility of choosing the optimum level of participation within the combination of programs selected, even though this combination was not optimum.

Actual versus Optimum Program Participation

The solution value of the objective function for alternative program combinations provided the basis for comparing actual with linear programmed optimum choices. A summary of these comparisons appears in Table 1.

Table 2 is a summary of the information in Table 1. In 49 of the 80 observations, the optimum combination of programs was chosen; in 38 cases

Table 1. Summary of actual and optimum levels of participation in wheat and feed grain programs for 1963 to 1966[1]

Farm Number	1963		1964		1965		1966	
	Actual	Optimum	Actual	Optimum	Actual	Optimum	Actual	Optimum
1	3*	3	2*	3	1	1	2*	2
2	3*	4	2	2	2	2	2	2
3	4*	3	2	2	2	2	2	2
4	4	2	1	1	2	1	1	1
5	1	4	2	2	2*	2	2	2
6	1	4	2*	1	1	1	1	1
7	2	4	1	1	1	2	2	1
8	4*	3	2*	2	1	2	2*	2
9	3*	3	2*	2	2	1	1	1
10	4	4	2	2	1	2	2*	2
11	3*	4	2*	2	2	1	1*	1
12	3*	3	2*	2	2*	2	1	2
13	3*	1	2*	2	1	1	2*	2
14	3*	4	2	2	1	2	1*	2
15	3	2	2*	2	2*	2	2	1
16	1	3	1	3	1	3	1	1
17	3*	3	2*	2	1	2	1*	1
18	3*	3	2*	2	1	1	1*	1
19	3*	3	2*	2	2	1	2	1
20	3*	4	1*	1	1*	1	1*	1

*The optimum level of participation was selected within the particular program combination.

[1]Numbers in the body of the table represent wheat and feed grain program combinations and should be interpreted as follows:

(1) Participate in both wheat and feed grain programs.
(2) Participate in the wheat program but not in the feed grain program.
(3) No participation in either program.
(4) Participate in feed grain program but not in the wheat program.

Table 2. Summary of farmer successes in selecting optimum participation in wheat and feed grain programs

Item	Operators made the optimum selection				
	At least one year	At least two years	At least three years	At least four years	TOTAL
	(No.)	(No.)	(No.)	(No.)	(No.)
Operators selected:					
Optimum combination of programs...............	20	17	11	1	49
Optimum level of participation in program combination selected.........	17	12	8	1	38
Optimum combination of programs and level of participation..........	13	11	4	0	28

the best level of participation within programs was selected, and in 28 instances both the optimum combination and level of participation occurred.

Not all farmers were equally adept at selecting the optimum. The optimum combination of programs was selected 61 percent of the time. Eighty-five percent of the farmers were able to pick the optimum combination at least two out of four years, while 55 percent were successful for at least three years. The optimum level of participation was chosen by 60 percent of the operators at least two years, and 40 percent were successful for three years. Selecting both optimum combinations and levels of participation was more difficult. This was accomplished 35 percent of the time. Sixty-five percent of the operators picked the optimum combination and optimum level within programs at least one year; however, only 20 percent were successful at least three years.

Factors Influencing Program Choices

Factors found to influence the farmers' ability to choose optimum participation in government wheat and feed grain programs were year-to-year changes in the programs and associated incentives, methods of making decisions, and certain characteristics of the farms and farm operators.

The number of farmers making optimum choices changed from year to year. In 1963 the poorest choices of program combinations were made of the four-year period, but the largest number of farmers selected the optimum level of participation. In 1964, choices of optimum program combinations were highest, then declined in 1965, and picked up again in 1966. The numbers of farmers who chose the optimum level of participation declined continuously through 1965, but increased some in 1966.

Much of the variation in optimum choices over time can be attributed to changes in wheat and feed grain programs. The 1963 program for barley was similar to that in 1962, but the wheat program became optimal for the first time in 1963. The 1962 wheat program stipulated that farmers were free to choose participation or nonparticipation. However, penalties for nonparticipation were severe enough that most farmers recognized little opportunity for choice. The program for 1963 allowed farmers the option of either planting their full allotments and receiving the regular price support payments or diverting part of their allotments, receiving diversion payments, and obtaining a higher price support rate. Many farmers chose to plant their full allotments without giving sufficient consideration to the alternatives.

Selecting the optimum level of participation within any given combination of programs was easier in 1963 than in subsequent years, since there were fewer alternatives for those who chose to participate.

The 1964 wheat program added two new features which multiplied the farmers' choices. These were marketing certificates paid on a percentage of the wheat production and the alternative of nonparticipation with any program, and planting wheat or barley fence-to-fence. Lower wheat prices in the market also made the choice of diversion more significant. However, the problems of choice created by these additional alternatives were offset in 1964 by a stipulation that farmers could wait until May 15 to commit themselves to a particular level of participation. The sign-up date for 1963, 1965, and 1966 was March 15. This additional time allowed farmers to more adequately assess their alternatives in the light of expected market prices and productivity on their farms. Therefore, they did much better as a group in choosing programs than in the preceding year or those that followed.

In 1965 wheat and barley programs were basically the same as in 1964, except that the possibility of substituting one grain for the other was included. This additional alternative made it difficult for farmers to choose either the optimum combination of programs or the optimum level of participation. Only 4 of the 20 farmers succeeded in selecting the optimum at both levels of choice.

The program for 1966 was only slightly different than that for 1965. It stipulated that price support payments on barley would be limited to 50 percent of the base acreage, whereas in previous years payments were made on all acres planted under the program. Because of the similarity with the 1965 programs, more farmers were successful in choosing the optimum plans.

Selecting a combination of programs and level of participation was a major concern of the farmers in the study. Past experience, personal calculations, decisions of other farmers, and local Agricultural Stabilization and Conservation Service office personnel were used in making program choices.

The analysis revealed that of 60 possible inter-year comparisons, in 23 cases the combination of programs selected was the same as that of the previous year (Table 3). In 14 of these 23 selections, the combination chosen was optimum. In 25 cases the program combination chosen was the same as the optimum combination for the previous year. Nineteen of these were also optimum for the current year. These data indicate that farmers were strongly influenced by past experience.

An aggregate comparison was made between the actual and optimum program participation. Table 4 contains a summary of the relevant data. Differences in both acreage and production were relatively small. The average percentage which the difference between actual and optimum acreage and production were of the actual acreage and production came to approximately the following proportions: for wheat acreage 2.9 percent, and for wheat production 3.3 percent; for barley acreage 14.7 percent, and for barley production 12.4 percent. There was little difference in the percentages relating to wheat over the four years. However, differences in barley acreages and production rose to about 23 percent and 19 percent, respectively, in 1966. In 1964, the difference was down to about 9 percent for acreage, while in 1965 the percentage related to production was about 16 percent. Barley was more adversely affected than wheat when farmers failed to choose the optimum programs.

The average difference in net revenue over the four years was approximately 3 percent of actual net revenue. Total income foregone by choosing sub-optimum participation in government programs over the four years amounted to $71,868.00, or an average of $897.60 per farm per year. Most of this loss occurred in 1965 when the substitution alternative was first introduced.

Regression analysis provided the means for deriving relationships between characteristics of the farm operators (Appendix C) and differences between actual and optimum choices of participation in wheat and feed grain programs. The equation used was as follows:

(Equation I)

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

where

Y = the four-year average percentage which the difference between the actual and optimum net revenues was of the average optimum net revenues for 1963 to 1966.

X_1 = total cropland acres per farm.

X_2 = long-run average wheat yield per farm.

Table 3. Inter-year comparisons of program participation

Item	Inter-year comparison			
	1963-64	1964-65	1965-66	TOTAL
	(No.)	(No.)	(No.)	(No.)
Farmers' selection of programs for this year was the same as that of last year......................	1	11	11	23
Farmers' selection of programs this year was the same as last year and was optimum this year.....	0	6	8	14
Farmers selected last year's optimum programs for this year......................	1	11	13	25
Farmers' selection of programs this year was optimum last year and also optimum this year....	1	7	11	19
If farmers had selected last year's optimum for this year, they would have chosen the optimum for this year.................	2	14	14	30

Table 4. Aggregate actual and optimum wheat and barley production for 1963 to 1966, 20 wheat farms, Columbia Basin, Oregon

Item	Unit	1963	1964	1965	1966
Wheat acres					
Actual..........	Acre	8,221.1	7,448.9	8,658.2	7,943.4
Optimum.........	Acre	8,418.4	7,299.1	8,683.0	8,492.6
Difference......	Acre	197.3	149.8	24.8	549.2
Difference as percentage of actual acres..	Percent	2.4	2.0	.3	6.9
Barley acres					
Actual..........	Acre	3,366.1	2,827.6	2,086.5	2,510.9
Optimum.........	Acre	3,006.8	3,073.0	2,419.8	1,920.7
Difference......	Acre	359.3	245.4	333.3	590.2
Difference as percentage of actual acres..	Percent	10.7	8.7	16.0	23.5
Wheat production[1]					
Actual..........	Bushel	355,286.2	331,066.7	375,762.2	348,917.5
Optimum.........	Bushel	363,575.6	322,296.3	381,264.6	373,405.2
Difference......	Bushel	8,289.4	8,770.4	5,502.4	24,487.7
Difference as percentage of actual acres..	Percent	2.3	2.6	1.5	7.0
Barley production[1]					
Actual..........	Cwt.	59,663.0	48,952.6	34,359.3	42,449.0
Optimum.........	Cwt.	55,351.0	52,670.4	39,782.6	34,286.6
Difference......	Cwt.	4,312.0	3,717.8	5,423.3	8,162.4
Difference as percentage of actual acres..	Percent	7.2	7.6	15.8	19.2

[1]Based on long-run average yields multiplied by the crop acreage.

X_3 = years farming experience of the operator.

X_4 = education of the operator.

X_5 = long-run average family income.

It should be noted when interpreting the regression coefficients that an increasing value of Y indicates less accuracy in the predicted value.

The least-squares procedure was used to estimate the values of the parameters of the equation. The derived equation with all variables included was as follows:

(Equation II)

$$Y = -.55509 - \underset{(.000025)}{.002X_1} + \underset{(.00104)}{.00383X_2} + \underset{(.00132)}{.00188X_3}$$

$$- \underset{(.00473)}{.0073X_4} \div \underset{(.000001426)}{.000003X_5}$$

The numbers in parentheses are the standard errors of the respective coefficients. Parameters X_1, X_2, and X_5 were significant at both the 0.05 and 0.01 level. The coefficient of determination (r^2) was 0.57 while the coefficient of multiple correlation (r) was 0.75.

The sign on the coefficient for X_1 indicated that farmers with larger acreages made better decisions than those with smaller farms. A positive relationship occurred between the dependent variable and X_3 and X_5, which indicated that older farmers and those with high incomes tended to make the poorer choices. A negative association between education and the dependent variable was the type which logically would be expected *a priori*. The positive association between wheat productivity and the dependent variable required closer consideration.

It was found that much of the error occurred in choices of participants in 1965 and 1966, years when the substitution clause was in effect. Some farmers failed to substitute wheat for barley when they should have, while others underestimated the value of barley and substituted wheat for it when this action was not the most profitable. Also, higher wheat yields would make any error in choice appear more obvious when measured by net revenue.

MODEL II RESULTS

A comparison of the maximum-profit organizations with the actual farm organizations was summarized on both an individual farm and an aggregate basis. A conformity index was developed to measure the degree of association between the calculated and actual farm organization in terms of fixed labor and land resource use patterns and enterprise combinations on each farm.

Individual farm comparisons appear in Table 5. Differences in net revenue ranged from 2 percent to a high of 71 percent of actual farm net revenue. The largest difference in terms of dollars was $10,698, which was 17 percent of the actual net revenue for the particular farm. On 15 farms the difference in net revenue was less than 10 percent of the actual value. On two other farms the difference was between 10 and 20 percent of the actual quantity.

The conformity indices suggest that the maximum-profit models did not predict the organization of all farms with a high degree of accuracy. The average index for the labor use pattern was 0.78; for the land use pattern, 0.89; and for the enterprise combination, 0.78. Land use patterns were predicted more accurately than those for labor use. This was attributed partly to a more limited number of uses for cropland than for labor. Also, cropland use was dominated by two highly productive enterprises, which was not true with labor. It should be noted that organization was predicted with less accuracy on farms which had irrigated land than on those with only dry cropland.

When actual and estimated production were aggregated for all of the farms, it was found that major enterprises were predicted with some degree of accuracy, while the sizes of supplementary enterprises, irrigated crops, and livestock enterprises were poorly represented by the maximum-profit models (Table 6). Wheat and barley production, which were the primary uses of dry cropland, were predicted with an error of only 2 percent. Beef cow numbers were also predicted fairly well. Their occurrence was tied closely to the presence of non-cropland on the farms, for which there was no alternative use. Irrigated land was used primarily to provide forage and hay for the cow herd. The maximum-profit organization specified that small grains should be produced on much of this irrigated land, and that more hay be purchased. In the calculated solutions, the occurrence of brood sows and cattle feedlots were dependent upon the quantity of fixed labor available during winter months. In the actual organizations, this labor was not being entirely used.

Since the aggregation was based on a population of farms, the differences observed were due primarily to specification error and were free from aggregation bias.

Table 5. A comparison of linear programmed organization with actual organization for the individual farm

Farm number	Net Revenue				Conformity indices[1] relating linear programmed to actual farm organization					
					Maximum profit model			Least cost model		
	Actual	Linear programmed	Difference	Difference as a per-cent of actual	Labor use pattern	Land use pattern	Enterprise combination	Labor use pattern	Land use pattern	Enterprise combination
	(Dollars)	(Dollars)	(Dollars)	(Percent)						
1	44,296	46,635	2,339	5	0.72	0.98	0.94	0.82	0.99	0.99
2	30,991	32,752	1,761	6	.94	.96	1.00	.88	.96	1.00
3	57,365	59,061	1,696	3	.89	.95	.89	.97	.96	.99
4*	10,637	15,313	4,676	44	.77	.86	.66	.35	.66	.70
5*	34,000	34,529	529	2	.77	.84	.55	.50	.84	.68
6	28,650	30,030	1,380	5	.87	.85	.91	.77	.92	.95
7*	72,450	77,566	5,116	7	.70	.82	.60	.72	.93	.90
8	14,000	15,901	1,901	14	.84	.89	.73	.68	.84	.75
9	39,382	41,726	2,344	6	.91	.97	.65	.89	.97	.65
10*	63,500	74,198	10,698	17	.69	.92	.68	.44	.88	.78
11*	34,280	36,693	2,413	7	.67	.85	.57	.66	.88	.74
12	42,195	43,634	1,439	3	.77	.98	1.00	.98	.98	1.00
13*	65,780	68,258	2,478	4	.83	.99	.66	.97	.99	.60
14*	78,009	82,326	4,317	6	.94	.97	1.00	.99	1.00	1.00
15	15,685	16,356	671	4	.89	.99	.97	.94	.99	.97
16*	14,297	24,432	10,135	71	.11	.24	.52	.11	.16	.63
17	47,763	51,530	3,767	8	.73	.94	.83	.63	.92	.86
18	56,418	58,813	2,395	4	.79	.95	.88	.93	.95	.92
19	19,545	23,873	4,328	22	.70	.96	.66	.94	.96	1.00
20	19,000	19,975	975	5	.98	.89	.98	.94	.92	.95

*Farms with irrigated cropland.

[1]The conformity indices compare the linear programmed farm organizations with the actual farm organization. They are based on the following formulas:

For labor and land resource allocation patterns

$$I = \frac{\Sigma(X_{i2} \leq X_{i1})}{\Sigma X_{i2}} \quad \text{where } 0 \leq I \leq 1.00$$

For enterprise combination

$$I = \frac{\Sigma X_{i3}}{\Sigma X_{i4}} \quad \text{where } 0 \leq I \leq 1.00$$

Table 5 - Footnote 1 -- Continued

where

I = The conformity index for labor (land). This measures the proportion of the labor (land) resource in the calculated solution which was allocated correctly.

X_{i1} = The quantity of labor actually allocated to the i^{th} enterprise (slack labor was treated as an enterprise).

X_{i2} = The quantity of labor (land) used by the i^{th} enterprise in the programmed solution but not exceeding the quantity used for the same enterprise in the actual organization where only enterprises in the actual organization are considered.

where

I = The conformity index for enterprise combination.

X_{i3} = The weighted value of the i^{th} enterprise in the programmed solution that was correctly selected when compared with the actual organization where per unit net revenues were used as weights. Excluding as well as including enterprises was considered to be a choice.

ΣX_{i4} = The sum of the weighted value of all enterprise alternatives for the farm.

Table 6. Aggregate comparison of linear programmed farm organization with actual farm organizations

	Unit	Actual organization	Maximum-profit organization	Difference	Difference as percent of actual organization	Least-cost organization	Difference	Difference as percent of actual organization
Dryland crops:								
Wheat............	Acres	7,969	7,818	151	2	7,725	244	3
Barley...........	Acres	3,337	3,405	68	2	3,826	489	15
Grain hay........	Acres	530	683	153	29	482	48	9
Alfalfa hay......	Acres	191	342	151	79	194	3	2
Improved pasture.	Acres	272	450	178	65	29	243	89
Irrigated crops:								
Wheat............	Acres	68	243	175	257	334	266	391
Barley...........	Acres	12	147	135	1,125	122	110	917
Pasture..........	Acres	289	112	177	61	28	261	90
Alfalfa hay......	Acres	545	166	379	70	72	473	87
Corn silage......	Acres	---	30	30	---	---	---	---
Livestock:								
Beef cows........	Head	1,434	1,230	204	14	944	490	34
Brood sows.......	Head	40	74	34	85	33	7	17
Fat cattle, feed-lot..........	Head	507	2,201	1,694	334	249	258	51
Fat cattle, grass........	Head	100	56	44	44	39	61	61

FACTORS CAUSING DIFFERENCES BETWEEN ACTUAL AND CALCULATED FARM ORGANIZATION

Characteristics of the programming models and attributes of the farm operators were investigated as causes for the observed differences between actual and maximum-profit farm organizations.

A sensitivity analysis with selected farms indicated that the solutions were stable when product prices were varied one standard deviation above and below the average price for the particular product. Therefore, the assumption regarding price expectations did not appear to be critical in the analysis. All restraints were checked for accuracy with the farmers after the models were constructed and one set of solutions was calculated. By following this procedure, it was assumed that the nature of the restraints was valid. Errors in input data may have been present. However, these figures were also verified by the farmers and therefore were assumed to be correct.

Maximum-Profit Criterion

The assumption of profit maximization did not accurately reflect the objectives of the farmers as suggested by their current farm organization. As an alternative, current farm organization was predicted with models which assumed an objective of minimizing the cost of maintaining the current level of income. Indices comparing these solutions with the actual organization appear in Table 5.

These indices indicate that the maximum-profit models predicted labor use patterns on 10 farms better than the least-cost models. On one farm the indices were identical for both models, while on nine farms the least-cost models did a better job. Neither of the models predicted labor use patterns accurately. The average of all labor use indices for the maximum-profit models was 0.78, while the average for the least-cost models was 0.76.

Both models predicted land use patterns better than labor use patterns. On an average the indices were 0.89 for both models. On seven farms the least-cost models predicted best, in five cases the maximum-profit models did best, and on eight farms the indices were identical for both models.

Enterprise combination was predicted more accurately by the least-cost models for 13 farms and by the maximum-profit models for 2 farms. Both models predicted with the same accuracy on five farms.

Enterprise Alternatives

The assumption that physically and economically feasible enterprises were acceptable alternatives did not prove to be correct for every farmer.

This was particularly true of cattle feedlots and brood sow enterprises. Attitudes of the farmers were important factors in selecting enterprises (Table 7). The maximum-profit solutions predicted that feedlots would appear on 19 of the 20 farms. Yet, five farmers indicated a personal dislike for cattle feeding and therefore did not have a feedlot, even though it would have been profitable for them. Brood sows were predicted for four farms, but actually occurred on only two. Again, the farmers indicated a dislike for hogs. Predictions of resource use patterns and enterprise combinations would have been better if only enterprises which were psychologically as well as physically and economically acceptable were included as alternatives.

Farm Operators

Characteristics of the farm operators which were considered *a priori* as possible factors which would help explain differences between actual and linear programmed farm organization were: years of farming experience; years of formal education; number of dependent children; annual family income; and age of the operator (Appendix C).

Multiple regression analysis was used to estimate the cumulative association which existed between these characteristics of the farmers and the differences which occurred between the actual and programmed farm organization (Table 8). The general form of the equation used was as follows:

(Equation III)

$$Y_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

where $i = 1$ to 4

and where

Y_1 = Difference between the actual and maximum profit net revenues expressed as a percentage of the actual net revenue.

Y_2 = Maximum profit labor conformity index.

Y_3 = Maximum profit land conformity index.

Y_4 = Maximum profit enterprise conformity index.

The calculated coefficients appear in Table 8. It should be noted that an increase in the value of Y_1 indicates less accuracy, while an increase in the values of Y_2, Y_3, and Y_4 denotes greater accuracy in the predicted values. The coefficients relating net revenue differences, Y_1, to the independent variables were negative in all cases. This indicates that as the numerical value of each characteristic increased, the index of net revenue difference decreased. Coefficients for the labor, Y_2, and the land, Y_3, use equations

Table 7. Attitudes of farmers toward brood sow and cattle fattening enterprises

Farm number	Brood sow enterprise			Cattle feedlot enterprise		
	Feasible on farm	Considered starting	Personal dislike	Feasible on farm	Considered starting	Personal dislike
1	yes	no	yes	yes	no	yes
2	yes	yes	yes	1/		
3	yes	no	no	yes	no	yes
4	yes	yes	no	yes	no	no
5	yes	no	yes	1/		
6	yes	yes	yes	yes	yes	no
7	yes	no	yes	1/		
8	yes	no	no	yes	yes	no
9	1/			1/		
10	yes	yes	yes	1/		
11	yes	yes	yes	yes	no	no
12	yes	no	yes	1/		
13	yes	no	yes	yes	yes	yes
14	yes	no	yes	1/		
15	1/			yes	no	no
16	yes	yes	yes	yes	yes	yes
17	yes	no	no	yes	no	no
18	yes	no	yes	yes	yes	yes
19	yes	yes	yes	no	no	no
20	yes	yes	yes	1/		

1/ The enterprise was already on the farm.

Table 8. Regression coefficients relating characteristics of farm operators to measured differences between actual and profit maximizing farm organization

Dependent variables[1]	Independent variables						
	Farming experience X_1	Formal education X_2	Family income X_3	Age of operator X_4	Dependent children X_5	r	r^2
Income difference Y_1	-.0054311	-.0070679	-.0000058*	-.0034183	-.0570854*	.73*	.54
Labor index Y_2	.0155029	.0019088	.0000071	-.0018371	.0840469	.57*	.33
Land index Y_3	.088383	.0072635	.0000049	-.0000060	.0698317*	.54*	.29
Enterprise index Y_4	.0122259	.0468588*	-.0000101	-.0131330	.0140162	.63*	.40

*Significant at the 0.05 level.

[1]See footnote 1, Table 5.

were all positive except for those associated with age of the operator. These variables accounted for a relatively small proportion of the total variation in Y_2 and Y_3. The coefficients of determination were .33 and .29, respectively. Differences in enterprise combinations, as reflected by the enterprise conformity indices Y_4, were positively correlated with all of the characteristics except family income and age of operator. The proportion of total variation in Y_4, explained by the independent variables, amounted to .40.

This analysis indicates that an association existed between measured differences of actual and maximum-profit programmed farm organizations and certain characteristics of the farmers. Farmers with larger families tend to approach the maximum-profit farm organization. Education was another factor of significance. Those individuals with more years of formal education were closer to the maximum-profit solution than those who did not have this additional training. Older farmers tended to have motives other than profit maximization, although the tendency was not a strong one. High incomes also appeared to be associated with individuals who had approached the programmed solution.

CONCLUSIONS

As a result of this study, the following conclusions were reached:

1. The maximum-profit programming models used in this study did not accurately predict all of the decisions of the farmers related to enterprise selection and resource use.

2. Profit maximization was not the exclusive objective of the farmers. They acted as profit maximizers in making some decisions, and not in others. The minimum-cost objective described the objectives of more farmers in this study than did the maximum-profit objective.

3. The maximum-profit linear programming models predicted more accurately in the short-run framework than in the longer run situation.

4. The models predicted the production for major farm enterprises better than production for supplementary enterprises.

5. Errors in specification of enterprises in the models were a major factor which created differences between actual and programmed farm organization. Enterprises must not only be physically and economically feasible, but also psychologically acceptable to the farmer.

6. Certain characteristics of the farmers may provide a means for establishing their objectives. Education and the number of

dependents were found to be the most significant in this study. Age and experience could also be important.

7. A continuation of this type of analysis would prove fruitful in establishing procedures to reduce discrepancies between actual and programmed solutions which arise due to errors in specification of the model.

IMPLICATIONS OF THE STUDY

The objectives of this study were meant to be suggestive and not definitive. They were to center attention on errors which can arise in supply response and adjustment studies based on the maximum-profit linear programming approach because of model specification. Researchers using this approach have recognized the presence of this type of error, but have not been able to assess its magnitude or specific steps which could be taken to reduce or eliminate it. The results of this investigation suggest that the predictive value of the linear programming technique could be improved through a continuation of this type of analysis. This analysis could help isolate conditions under which large amounts of specification error might be expected, and thereby provide a basis for evaluating the usefulness of the tool for specific situations. It might also provide the basis for stratifying a population so that models could be constructed for each strata, which would minimize the specification error.

The procedures used in this investigation suggest an additional use for linear programming. It has historically been applied in situations where the objective was to specify the optimum way of attaining a given objective or to predict farm production. In this study it was used to investigate factors which caused differences to arise between actual and normative solutions.

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APPENDIX A

EXPLANATION OF MODEL I

Table 9. The general form of Model I

Equation number		Unit	B_i	Support wheat A	Support wheat B	Wheat A	Wheat B	Subst. wheat for barley	Divert wheat	Divert barley
1	Cost......................	Dol.	0 =	$-P_1$	$-P_2$	$-P_3$	$-P_4$	$-P_5$	$-P_6$	$-P_7$
2	Cropland A..............	Acre	$B_1 \geq$	1		1				
3	Cropland B..............	Acre	$B_2 \geq$	.139	1.139		1	1.25	1	1
4	Wheat allotment..........	Acre	$B_3 \geq$	1	1	1	1		1	
5	Max. wheat diversion.....	Acre	$B_4 \geq$						1	
6	Barley base.............	Acre	$B_5 \geq$					1		1
7	Max. barley diversion....	Acre	$B_6 \geq$							1
8	Actual wheat diversion...	Acre	$B_7 \geq$						-1	
9	Actual barley diversion..	Acre	$B_8 \geq$							-1
10	Max. wheat with pay......	Acre	$B_9 \geq$	1	1					
11	Wheat account...........	Bu.	0 $\geq$	-A	-A	-A	-A	-A		
12	Barley account..........	Cwt.	0 $\geq$							

Table 9. The general form of Model I -- Continued

Equation number	Support barley A	Support barley B	Subst. barley for wheat	No wheat program A	No wheat program B	No barley program A	No barley program B	Sell wheat	Sell barley
1	$-P_8$	$-P_9$	$-P_{10}$	$-P_{11}$	$-P_{12}$	$-P_{13}$	$-P_{14}$	$-P_{15}$	$-P_{16}$
2	1			1		1			
3		1	1		1		1		
4		1							
5									
6	1	1							
7									
8									
9									
10									
11				-A	-A			1	
12	-A	-A	-A			-A	-A		1

Interpretation of Model I

Restraints

B_1 and B_2 -- Cropland of different qualities available for crops in the particular year. Does not include summer fallow.

B_3 -- Total farm wheat allotment. In 1963 there were two wheat allotment restraints. The first restricted production to the total allotted acres for the farm if the producer chose to stay out of the wheat program, while the second limited production to 20 percent less than the total farm allotment, which was a requirement for those who complied with the wheat program for that year.

B_4 -- Maximum acres of wheat allotment which could be diverted for payment. This is the amount beyond the minimum required for participation in the wheat program.

B_5 -- Total farm barley base.

B_6 -- Maximum acres of barley base which could be diverted for payment.

B_7 -- An accounting row for wheat diversion. Initially contained the minimum diverted acres required for participation in the program.

B_8 -- An accounting row for barley diversion. Initially contained the minimum diverted acreage required for participation in the program.

B_9 -- The maximum acres of wheat which could receive price support payments. This restraint was absent from the 1963 models, since price support payments were made on all acres seeded under the wheat program. In 1966 a similar equation was included for barley, since that was the only year that support payments were provided on less than 100 percent of the acres seeded under the feed grain program.

Activities

P_1 and P_2 -- Allowed for wheat production with price support payments on land of various qualities. Under the wheat program, a minimum diversion was required by all participants. The amount of this requirement is the initial restraint level in B_7. To deduct this acreage from the total cropland restraint when these activities entered the solution, the land use coefficients were set at a level which would accomplish this. Since diversion generally took place on the least productive land, this requirement was built into the model. The cost coefficients were established by subtracting the price support payment per acre from the variable costs of production.

P_3 and P_4 -- Allowed for production of wheat under the program which would not receive price support payments. Cost coefficients in this case were simply variable costs of production.

P_5 -- Took into account the possibility of substituting wheat for barley when both programs were entered. The explanation of the land coefficient is the same as the land coefficients of P_1 and P_2. In this case, however, the initial diversion requirement for entering the program was higher. The activity is restrained by the barley base, since substitution could not exceed this quantity. The cost coefficient was the same as that for P_3 and P_4.

P_6 -- The activity which allowed additional wheat diversion within the program. It drew from the least productive land, the wheat allotment, and the maximum wheat diversion restraints.

P_7 -- The same as P_6 except that it applied to additional barley diversion.

P_8 and P_9 -- Activities which allowed barley production under the barley program. The explanation of the land coefficients is the same as for those in P_1 and P_2. In 1966 these activities were restricted to 50 percent of the barley base, since that acreage was eligible for price support payments. Additional activities similar to P_3 and P_4 were added for barley, to allow for production under the program which would not receive price supports. Cost coefficients were calculated in the same manner as those in P_1 and P_2.

P_{10} -- Allowed for the substitution of barley for wheat under the programs and drew from the wheat allotment restraint. The cost coefficient was the variable cost per acre of producing barley.

P_{11} to P_{14} -- Represented production of wheat and barley when there was no participation in the wheat or feed grain programs. Costs were simply variable costs of production per acre.

P_{15} and P_{16} -- Wheat and barley selling activities.

Programming Procedures

The solution to the model involved discrete choices among the activities. Since standard programming procedures were unable to solve this type of problem, an indirect approach was used. There were four alternative combinations of programs represented by an equal number of sets of activities. Solutions were calculated for each of these sets. The optimum solution was found by comparing the objective functions. The activities included in each of these sub-models were as follows:

A -- Participation in both wheat and feed grain programs:

$P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8, P_9, P_{10}, P_{15}, P_{16}$.

B -- Participation in wheat program only:

$P_1, P_2, P_3, P_4, P_6, P_{13}, P_{14}, P_{15}, P_{16}$.

C -- Participation in neither wheat nor feed grain programs:

$P_{11}, P_{12}, P_{13}, P_{14}, P_{15}, P_{16}$.

D -- Participation in barley program only:

$P_7, P_8, P_9, P_{11}, P_{12}, P_{15}, P_{16}$.

Wheat Program*

1963

1 -- Stay out of the program by complying only with the farm acreage allotment and receive regular price supports.

2 -- Comply with the program by diverting a minimum of 20 percent of the farm allotment to conserving uses and receive an additional 18 cents payment per bushel above the regular price support.

3 -- Earn diversion payments by diverting a minimum of 20 percent and not more than 50 percent of the farm allotment to conserving uses.

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*Information on wheat and feed grain programs was provided by the Wasco County Agricultural Stabilization office.

1964

1 -- Stay out of the program completely by ignoring the farm allotment, plant all the wheat desired, and receive as a result only the market price for wheat.

2 -- Comply with the program by diverting at least 11.11 percent of the farm allotment to conserving uses and receive a price support in the form of marketing certificates. These certificates were issued on 90 percent of the normal production. Forty-five percent were in the form of domestic marketing certificates, while the remainder were issued as export certificates.

3 -- Earn diversion payments by diverting a minimum of 11.11 percent and no more than 20 percent of the farm allotments to conserving uses.

1965

1 -- Stay out of the program completely by ignoring the farm allotment, plant all the wheat desired, and receive as a result only the market price for wheat.

2 -- Comply with the program by diverting at least 10 percent of the year's allotment to conserving uses and receive a price support payment in the form of domestic and export marketing certificates on 80 percent of the normal production.

3 -- Comply with provisions of both wheat and feed grain programs and substitute one grain crop for the other. No price supports would be paid on this additional production.

4 -- Earn diversion payments by diverting allotment in addition to the minimum required. A maximum of 20 percent of the year's allotment could be diverted for payment.

1966

1 -- Stay out of the program completely by ignoring the farm allotment, plant all the wheat desired, and receive as a result only the market price for wheat.

2 -- Comply with the program by diverting a minimum of 15 percent of the year's allotment to conserving uses and receive a price support payment in the form of domestic marketing

certificates on 45 percent of the normal production.

3 -- Comply with provisions of both wheat and feed grain programs and substitute one grain crop for the other. No price supports would be paid on this additional production.

4 -- Earn diversion payments by diverting allotment in addition to the minimum required. A maximum of 50 percent of the year's allotment could be diverted for payment.

Feed Grain Program

1963

1 -- Stay out of the program completely and plant all the barley desired.

2 -- Comply with the program by diverting a minimum of 20 percent of the year's feed grain base to conserving uses and receive price support payments on all feed grains produced under the program.

3 -- Earn diversion payments on the minimum diversion requirement for participation and any additional diversion up to 40 percent of the year's base acreage.

1964

1 -- The feed grain program alternatives for 1964 were identical with those in 1963 except that the maximum diversion was increased to 50 percent.

1965

1 -- The 1965 feed grain program alternatives were identical with those in 1964 except for the addition of the substitution clause as described in the wheat program for 1965.

1966

1 -- The 1966 feed grain program alternatives were identical with those in 1965 except that price support payments were limited to 50 percent of the feed grain base for the year.

APPENDIX B

EXPLANATION OF MODEL II

Table 10. The general form of Model II

Equation number		Unit	B_i		Nurse crop	Alfalfa 5 years	Pasture 5 years	Wheat after G.M.	Corn after G.M.	Wheat after grain	Wheat I	Fallow I
1	Cost.................	Dol.	0	=	-P	-P	-P	-P	-P	-P	-P	-P
2	Irrigated land.......	Acres	B_1	=	1	5	5	1	1	1	1	1
3	Dryland..............	Acres	B_2	=				.12		.12	.12	
4	Wheat allotment......	Acres	B_3	=				1		1	1	
5	Nurse crop account...	Acres	0	>	-1	1	1					
6	Green manure account.	Acres	0	≥		-1	-1	1	1			
7	Grain to grain.......	Acres	0	≥				-1	-1	1		
8	Fallow to grain......	Acres	0	≥							1	-1
9	Max. grain hay.......	Acres	0	≥				-A		-A	-A	
10	Wheat account........	Bu.	0	≥				-A		-A	-A	
11	Barley account.......	Cwt.	0	≥								
12	Corn silage account..	Tons	0	≥					-A			
13	Pasture account......	AUM	0	≥			-A					
14	Range account........	AUM	B_{13}	≥								
15	Hog account..........	Cwt.	0	≥								
16	Calf account.........	Cwt.	0	≥								
17	Yearling account.....	Cwt.	0	≥								
18	Cull cow account.....	Cwt.	0	≥								
19	Grass fat account....	Cwt.	0	≥								
20	Labor period I.......	Hrs.	B_{19}	≥	A	A	A	A	A	A	A	A
21	Max. labor hire, period I..........	Hrs.	B_{20}	>								
22	Feed hay.............	AUM	0	≥								
23	Feed barley..........	Cwt.	0	≥								
24	Purchased yearlings..	Cwt.	0	≥								
25	Operating capital....	$100	0	≥	A	A	A	A	A	A	A	A
26	Investment capital...	$100	0	≥								
27	Fixed cash required..	$100	B_{26}	=								
28	Cash on hand.........	$100	B_{27}	>								
29	Credit...............	$100	0	≥	-A	-A	-A	-A	-A	-A	-A	-A
30	Credit K.............	$100	0	≥								

Continued

Table 10. The general form of Model II--Continued

Equation number		Unit	B_i		Nurse crop	Alfalfa 5 years	Pasture 5 years	Wheat after G.M.	Corn after G.M.	Wheat after grain	Wheat I	Fallow I
31	Credit F.............	$100	0	$\geq$								
32	Credit G.............	$100	0	$\geq$								
33												
34	Hay account..........	AUM	0	$\geq$								
35	Fat cattle account...	Cwt.	0	$\geq$								
36	K_1 credit............	$100	0	$\geq$	1							
37	K_2 credit............	$100	0	$\geq$		1						
38	K_3 credit............	$100	0	$\geq$			1					
39	K_4 credit............	$100	0	$\geq$				1				
40	K_5 credit............	$100	0	$\geq$					1			
41	K_6 credit............	$100	0	$\geq$						1		
42	K_7 credit............	$100	0	$\geq$							1	
43	K_8 credit............	$100	0	$\geq$								1
44	K_9 credit............	$100	0	$\geq$								
45	K_{10} credit...........	$100	0	$\geq$								
46	K_{11} credit...........	$100	0	$\geq$								
47	K_{12} credit...........	$100	0	$\geq$								
48	K_{13} credit...........	$100	0	$\geq$								
49	K_{14} credit...........	$100	0	$\geq$								
50	K_{15} credit...........	$100	0	$\geq$								
51	K_{16} credit...........	$100	0	$\geq$								
52	K_{17} credit...........	$100	0	$\geq$								
53	K_{18} credit...........	$100	0	$\geq$								
54	K_{19} credit...........	$100	0	$\geq$								
55	K_{20} credit...........	$100	0	$\geq$								
56	K_{21} credit...........	$100	0	$\geq$								

Continued

Table 10. The general form of Model II--Continued

Equation number	Wheat	Barley	Grain hay	Dryland alfalfa	Improved pasture	Cow-calf range	Cow-calf pasture	Brood sow	Calf to yrlg.	Feed-lot A	Feed-lot B	Grass fatten	Hay transfer
1	-P	-P	-P	-P	-P	-P	-P	-P	-P	-P	-P	-P	0
2													
3	2.12	2		1	1								
4	1												
.													
.													
.													
9	-A		1										
10	-A												
11		-A						A	A	A	A		
12											A		
13							A					A	
14					-A	A							
15								-A					
16						-A	-A		A				
17									-A	A		A	
18						-A	-A						
19												-A	
20	A	A	A	A	A	A	A	A	A	A	A	A	
21													
22			-A	-A		A	A		A				-1
23								A		A	A		
24											A		
25	A	A	A	A	A	A	A	A	A	A	A	A	
26						A	A	A		A	A		
27													
28													
29	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	
30								-A		-A	-A	-A	
31	-A	-A				-A	-A		A				
32													
33													
34													1

Continued

Table 10. The general form of Model II--Continued

Equation number	Wheat	Barley	Grain hay	Dryland alfalfa	Improved pasture	Cow-calf range	Cow-calf pasture	Brood sow	Calf to yrlg.	Feed-lot A	Feed-lot B	Grass fatten	Hay transfer
35								-A		-A	-A		
.													
.													
.													
44	1												
45		1											
46			1										
47				1									
48					1								
49						1							
50							1						
51								1					
52									1				
53										1			
54											1		
55													
56													

Continued

Table 10. The general form of Model II--Continued

Equation number	Barley trans-fer	Hire labor Period I	Buy barley	Buy hay	Buy calf	Buy yrlg.	Buy operating capital	Buy investment capital	Buy cash	Transfer credit F	Transfer credit K	Spend cash	In-vest cash
1	0	-P	-P	-P	-P	-P	-P	0	-P	-P	-P	0	0
2													
.													
.													
.													
11	1												
.													
.													
.													
16						-1							
.													
.													
.													
20		-9											
21		9											
22				-1									
23	-1		-1										
24						-1							
25		A		A			-1						
26								-1					
27										-1	-1	-1	
28									1			1	1
29							1						
30													
31	A									1			
32			A		A	A			-1				
33											1		
.													
.													
.													
55		1											
56				1									

Continued

Table 10. The general form of Model II--Continued

Equation number	Sell hogs	Sell hay	Sell calves	Sell grass fat	Sell fat cattle	Sell cull cows	Sell wheat	Sell barley
1	P	P	P	P	P	P	P	P
2								
.								
.								
.								
9							1	
10								1
.								
.								
.								
15	1							
16			1					
17								
18						1		
19				1				
.								
.								
.								
34		1						
35					1			

Continued

Table 10. The general form of Model II--Continued

Equation number	K_1 transfer	K_2 transfer	K_3 transfer	K_4 transfer	K_5 transfer	K_6 transfer	K_7 transfer	K_8 transfer	K_9 transfer	K_{10} transfer	K_{11} transfer	K_{12} transfer	K_{13} transfer
36	-1												
37		-1											
38			-1										
39				-1									
40					-1								
41						-1							
42							-1						
43								-1					
44									-1				
45										-1			
46											-1		
47												-1	
48													-1
.													
.													
.													
29	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A

Continued

Table 10. The general form of Model II--Continued

Equation number	K_{14} trans-fer	K_{15} trans-fer	K_{16} trans-fer	K_{17} trans-fer	K_{18} trans-fer	K_{19} trans-fer	K_{20} trans-fer	K_{21} trans-fer
36								
.								
.								
.								
49	-1							
50		-1						
51			-1					
52				-1				
53					-1			
54						-1		
55							-1	
56								-1
29	-A	-A	-A	-A	-A	-A	-A	-A

Interpretation of Model II

The Objective Function

Equation I contains the maximum-profit objective function. Negative P values indicate costs, while positive P values indicate product prices.

Irrigated Crop Rotation Activities

The first eight activities in Table 10 deal with irrigated crop production. From these activities, 19 different rotation programs are possible. Some of these are as follows:

1 - Nurse crop, alfalfa
2 - Nurse crop, pasture
3 - Nurse crop, alfalfa, pasture
4 - Nurse crop, alfalfa, wheat
5 - Nurse crop, alfalfa, wheat, wheat
6 - Nurse crop, alfalfa, corn
7 - Nurse crop, alfalfa, corn, wheat
8 - Nurse crop, pasture, wheat
9 - Nurse crop, pasture, wheat, wheat
10 - Nurse crop, pasture, corn
11 - Nurse crop, pasture, corn, wheat
12 - Nurse crop, alfalfa, pasture, wheat, wheat, corn

The alfalfa and pasture in these rotations each cover a five-year period. In this model the differences in yield which occur when a crop assumes a particular position in the rotation is illustrated by the two activities "wheat after G.M. (green manure)" and "wheat after grain". Different inputs are required to obtain a given yield when wheat follows a green manure crop than when it follows another grain crop. These differences are accounted for in the cost and technical coefficients. The two activities are placed in the model so that the first enters the solution only after a green manure crop, which in this case was either alfalfa hay or pasture, while the second must be preceded by either corn or wheat.

The rotation activities included in Model II are for purposes of illustration and represent only a part of the alternatives used in the actual farm models.

Dryland Crop Production Activities

Wheat, barley, grain hay, alfalfa, and improved pasture constituted the alternative uses for dry cropland. Wheat production was restricted by the farm allotment. There was no limitation on barley production, since much of the time farmers did not participate in the feed grain program. Grain hay production was limited to acreages diverted from wheat. There were no restrictions on dryland alfalfa or improved pasture. Grain hay and dryland alfalfa did not feed into the hay account (Equation 34), since it was assumed that both products were fed on the farm. Therefore, they entered directly into the hay feeding equation (Equation 22).

Each of the irrigated and dryland crop enterprises required operating capital to the extent of its variable costs of production (Equation 25). Each of them also generated credit equal to this variable cost of production (Equations 36 to 52 and Equation 29).

Dryland wheat and barley also added to credit (Equation 31) value equal to the difference between the gross revenue and variable costs of production. The significance of Equation 31 will be discussed in the credit section.

Cow-calf Activities

Two cow-calf activities were constructed. One represented production under range conditions and the other production on irrigated pasture. Forage, hay, and labor were the main physical inputs. Production included calves and cull cows (Equations 16 and 18). Capital requirements included both operating and investment capital. Operating costs included all fixed and variable costs of production. However, operating capital required was limited to the cash input. Investment capital covered only that required for the breeding herd.

The explanation of credit presented in the crop enterprise discussion also applies here.

Brood Sow Enterprise

The brood sow enterprise assumed two litters per year and that fattening would be done in confinement.

The brood sow enterprise uses operating capital and investment capital. It creates sufficient credit to cover its cost of production and credit equal to the difference between its gross revenue and cost of production which goes into Equation 33.

Cow to Yearling Enterprise

This was an intermediate activity which transformed home-grown or purchased calves into yearling feeders for the feedlot or for grass fattening.

Feedlot Enterprises

The two feedlot enterprises represent cattle fed a high barley ration and cattle fed a ration based on corn silage. The model also indicates that Feedlot B was restricted to fattening purchased yearlings. In the actual models there were additional feedlot activities which allowed purchased feeders to be fattened on high-barley rations and cattle raised on the farm to be fattened on a silage ration. A fully automated feeding system was assumed in both cases. The feedlot activities required both operating and investment capital. They contributed to credit (Equation 30).

Grass Fattening Enterprise

This activity was limited to farms which had irrigated land. It requires operating capital and contributes to credit (Equation 30).

Hay and Barley Transfer Activities

These activities simply transfer the related products from the product accounts to the feeding accounts. This makes it possible to purchase feeds for consumption and avoid the possibility of having them re-sold in the programming analysis.

Labor Hiring Activity

Labor could be hired from March through September in nine-hour units. During some months there was a maximum which the farmer could adequately supervise. For this reason the activity draws from Equation 21, which is the hiring limit for the particular labor period.

Commodity Purchase Activities

Barley, hay, calves, and yearlings could be purchased for on-farm use. The hay purchasing activity drew from the operating capital equation, since it was assumed that enterprises using this resource created sufficient credit for its purchase. Barley, calf, and yearling purchases drew from credit (Equation 32). The reason for this will be discussed in the credit section.

Capital and Credit Activities

Cash was required for four purposes: first, to provide for operating capital (Equation 25); second, to furnish investment resources for the cow-calf, brood sow, and feedlot enterprises (Equation 26); third, to purchase feed and livestock off the farm; and fourth, to meet the fixed cash requirements of the family and farming operation (Equation 27).

Sources of cash to meet these needs came first from cash on hand (Equation 28). This money could be used for fixed cash requirements by way of the "spend cash" activity, for operating capital by way of the "invest cash" activity, or for purchases of barley or livestock by means of the "buy cash" activity. The second source of cash was from credit created in the production of crops and livestock (Equation 29). This credit was used by the "buy operating capital" activity, which provided operating capital (Equation 25). The third source of cash came from additional credit created in the production of dryland grain crops and from the cow-calf enterprise which fed into Equation 31. It should be noted that the "barley transfer" and the "calf to yearling" activities draw from Equation 31. This is on the assumption that if these products are used on the farm they do not serve as credit, since they no longer exist in their original form. Credit from Equation 31 could be used to provide for fixed cash required (Equation 27), by means of the "transfer credit F" activity. The fourth source of cash came from credit created by the "brood sow", "feedlot", and "grass fattening" activities which fed into Equation 30. This credit could be used only for fixed cash required (Equation 27) and was transferred by the "transfer credit K" activity.

Selling Activities

These activities disposed of products grown on the farms.

Resource Restraints

Resources assumed to be limiting in the model were cropland, range land, the wheat allotment, and family and full-time hired labor. Equations were included for land of different productivity. The wheat allotment was the average for the years from 1963 to 1966. The labor restraints were uniform for all farms. The year was divided into five labor periods:

November - February

March - May

June

July - August

September - October

On farms where capital was limiting, the "cash on hand" restraint consisted of cash available at the beginning of the year.

APPENDIX C

CHARACTERISTICS OF FARMS AND FARM OPERATORS

Table 11. Land inventory and tenure for the sample farms

Farm number	Land owned			Land rented			Total land		
	Irrigated cropland	Dry cropland	Range	Irrigated cropland	Dry cropland	Range	Irrigated cropland	Dry cropland	Range
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
1	---	1,166	833	---	504	165	---	1,670	998
2	---	1,100	2,910	---	244	480	---	1,344	3,390
3	---	1,625	1,250	---	425	4,650	---	2,050	5,900
4	76	218	1,506	---	---	---	76	218	1,506
5	100	450	850	44	637	250	144	1,087	1,100
6	---	1,270	1,430	---	---	---	---	1,270	1,430
7	35	2,123	584	---	---	---	35	2,123	584
8	55	165	388	---	313	687	55	478	1,075
9	---	---	360	---	1,291	2,190	---	1,291	2,550
10	140	1,860	1,494	---	---	---	140	1,860	1,494
11	16	842	428	43	87	400	59	929	828
12	---	---	---	---	917	568	---	917	568
13	12	1,671	1,150	---	---	---	12	1,671	1,150
14	35	1,365	2,880	---	750	450	35	2,115	2,880
15	---	---	---	6	634	210	6	634	210
16	319	---	---	---	---	---	319	---	---
17	---	---	---	---	1,325	1,450	---	1,325	1,450
18	---	1,593	873	---	---	---	---	1,593	873
19	---	---	---	---	1,180	900	---	1,180	900
20	---	780	340	---	---	---	---	780	340
TOTAL	788	16,228	17,276	93	8,307	12,400	881	24,535	29,226

Table 12. Average yield of wheat and barley for the sample farms

Farm number	Wheat yield	Barley yield
	Bushels	Bushels
1	42.9*	44
2	28.7*	28
3	35.0*	37
4	34.0	37
5	34.6*	38
6	34.0	37
7	49.8*	57
8	24.0	35
9	36.3*	38
10	37.0	40
11	46.2*	37
12	56.0*	50
13	58.0*	45
14	45.0	37
15	51.0*	43
16	75.0	80
17	51.4*	40
18	52.0*	35
19	52.0*	46
20	40.9*	35
Average	40.9*	35

*Proven yield according to A.S.C.S. requirements.

Table 13. Personal statistics on farm operators

Farm number	Age of operator	Years farm operator	Years formal education	Dependent children	Family income from farm
	Number	Number	Number	Number	Dollars
1	42	18	12	2	5,000
	58	30	12		10,500
2	27	6	12	2	10,500
3	47	23	13	2	19,500
4	55	30	8	0	3,000
5	70	50	8	0	10,000
6	59	31	12	2	8,000
	50	21	13	0	24,000
7	49	21	13	0	24,000
8	56	41	12	1	4,000
9	42	20	12	5	14,000
10	47	27	12	2	13,000
	34	8	12	3	5,500
11	35	8	12	2	5,500
12	38	16	16	5	7,000
13	50	25	12	1	18,000
14	52	32	13	0	20,000
15	46	20	16	4	8,000
	50	25	12		3,200
16	48	25	12	0	3,200
17	46	22	12	3	11,000
18	53	30	20	0	27,000
19	46	21	12	3	5,000
20	44	21	12	3	7,500
Average	47.7	23.8	12.5	2.7	11,100

Table 14. Operator real estate and operating capital indebtedness

Farm number	Value of real estate	Real estate debt	Typical annual cash operating capital	Typical amount of annual cash operating capital borrowed[1]	Nonfarm financial interests
	Dollars	Dollars	Dollars	Dollars	
1	167,500	86,000	23,000	0	No
2	166,600	38,000	18,500	9,250	No
3	230,000	60,000	25,000	0	Yes[2]
4	68,000	9,000	8,500	8,500	No
5	97,000	0	21,000	0	No
6	185,750	40,000	20,000	10,000	No
7	386,515	0	30,000	0	Yes[2]
8	39,905	0	6,500	1,500	No
9	7,600	0	85,000	80,000	Yes[2]
10	435,940	134,376	90,000	90,000	No
11	152,220	115,000	30,000	30,000	No
12	---	---	12,500	0	Yes[2]
13	349,300	18,000	41,000	0	Yes[3]
14	230,400	50,000	75,000	0	Yes[3]
15	---	---	20,000	20,000	No
16	200,000	8,000	27,400	27,400	No
17	---	---	14,500	0	Yes[4]
18	327,330	81,832	50,000	0	Yes[5]
19	---	---	20,000	20,000	No
20	136,000	14,000	17,000	17,000	Yes[6]
Average	198,754[7]	40,888[7]	31,745	15,682	

[1]All farmers in this study used the local Production Credit Association as the main source of operating capital.

[2]Owned stocks, bonds, or both.

[3]Owned stocks, bonds, and a partnership in a business building in The Dalles.

[4]Owned stocks and an interest in The Dalles Livestock Auction.

[5]Owned stocks, bonds, and an interest in The Dalles Livestock Auction.

[6]Owned stocks, and was the county brand inspector.

[7]Average for the 16 farmers who owned real estate.