EFFICIENCY OF PRODUCTION ON CENTRAL ILLINOIS FARMS AS MEASURED BY DIFFERENCES BETWEEN ACTUAL INCOME AND LINEAR PROGRAMMING OPTIMA 1951-1957

BY

JEREMIAH EDWARD FRUIN

B.S., University of Illinois, 1958

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1959

URBANA, ILLINOIS

ACKNOWLEDGEMENT

The author wishes to express appreciation to Professor Vincent I. West and Professor Chester B. Baker for their guidance and helpful suggestions in the preparation of this thesis.

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CHAPTER I. INTRODUCTION

The ratio of prices received for farm products to prices paid by farmers dropped from 115 in 1947 to 82 in 1957. The decline was relieved only briefly during the Korean War. It stood at 107 in 1951. (17) In response to the less favorable economic conditions, many farmers have shifted occupations. The number of commercial farmers declined by 10 per cent (378,795) between 1950 and 1954. (18) Others increased the acreage of their farms. The average Illinois farm has increased in size from 161 acres in 1950 to 178 acres in 1957. (10) Mechanization and new technological developments have made this expansion in acreage possible while decreasing the total labor requirements in many instances.

Another solution has been for farmers to maintain the same acreage while making other adjustments in the farm business. Some of the most common of these have been the adding of more capital in the form of larger livestock enterprises, changing the kind or number of the enterprises within the farm business, or increasing the efficiency of production within the present farm structure, all while maintaining a constant acreage.

This study shall attempt to determine which of the latter two solutions has been most effective for the farms in the cash grain areas of the cornbelt.

CHAPTER II. STATEMENT OF HYPOTHESIS

Neoclassical theory states that each firm has an equilibrium position where the value of production due to the last increment of each resource which is added is exactly equal to the cost of the increment of the resource. This can be shown to always be the most profitable level for the firm to operate at except under monopolistic conditions. Alert management, therefore, strives to operate the firm at this equilibrium level where profit is greatest.

In agriculture, each farm operates as an individual firm under pure competition and therefore has an equilibrium level where the cost of the last increment of each resource is equal to value of the additional product from the last increment of each resource. Of course, this equilibrium level is constantly changing as the values of both resources and products fluctuate in the market place. One can obtain a measure of the efficiency of the farm organization by determining how close each of the resources used in production is to the equilibrium level.

However, such a method would become extremely tedious. It is also exceedingly difficult to obtain an accurate estimate of the marginal productivity of any individual resource under actual conditions. Since marginal productivity varies from farm to farm and between different enterprises on the same farm for each resource, a measure of efficiency which is easier to compute was needed for this problem. The efficient use of any individual resource was not the concern of the problem but rather how efficiently all the resources available on the farm were combined together. Linear programming

techniques were used to develop an aggregate measure of efficiency.

Linear programming is a mathematical procedure which can be used to derive the highest-return farming systems, given a set of assumptions concerning resource supplies, input-output ratios and prices of the goods the farmer must buy and sell. For a detailed explanation and description of the method see Linear Programming Methods (8). The accuracy and acceptability of the results are usually not limited by the above assumptions, which must be made whether the highest-returns organization is desired by linear programming, or other techniques. However, there are other assumptions, some of which are limiting, inherent in linear programming models. The simplicity of the model used here avoids making some of these assumptions. Others which pertain to this problem are discussed later when they arise.

One assumption of linear programming is that the production process of the farm can be broken down into a finite group of elementary processes or activities, which define all of the relevant production opportunities. This assumption makes programming a stronger tool for determining an optimal organization than production functions techniques since it allows programming to select one or a combination of similar enterprises with different input-output ratios (like different methods of feeding beef cattle) at the level or levels where the enterprises have favorable returns subject to the restrictions. Whole farm production functions cannot be used to distinguish between similar enterprises with different input-output coefficients but only between groups of enterprises in general categories such as "beef cattle." Whole farm production functions

also cannot be used to determine the optimal levels with precision but merely whether too much or too little of a resource is being used.

In developing this theoretical equilibrium level of profit by linear programming, the restricting factors were those resources which are fixed in the short run. One of the requirements of linear programming is that the production functions for these resources are homogeneous in the first degree. It is highly probable that these resources which are restrictive would very nearly meet these requirements if available in quantities up to several times the present level. Probably the resources and factors which are most limiting from the production function approach and least likely to meet the requirement of a linear production function are intangibles such as managerial ability, ambition, and the willingness to take risks.

Almost all farmers are constantly making changes in the organization of their farm business. Most of these changes are made either consciously or unconsciously for the purpose of arriving at an optimal organization in some sense. The types of optima for which most farmers strive are:

1a.) The neoclassical equilibrium point of maximum profit. This is a long run goal since farmers cannot adjust quickly enough to remain long at the optimal level. Also many farmers never have control of enough resources to reach the point of maximum profit.

1b.) The optimal use of the available fixed resources; the solution obtained by linear programming. This is frequently used as an optimal organization in the short run until the level of resources can be adjusted.

2.) An income above a certain level.

Most farmers operate at a point determined mainly by the criteria of 1b which is frequently the short run solution for 1a. Farmers usually have

several resources which are restrictive at a level where marginal revenue is greater than marginal cost. They then attempt to maximize profit by varying the non-restrictive resources.

In the present problem a similar type of optima was obtained. A linear programming estimate was made of the returns to the fixed resources, land, labor, and capital, subject to the restraints imposed by these resources and other restrictions. This is the estimate which was compared with the actual returns to these resources in obtaining a measure of the efficiency of the farm organization.

One distinction between the linear programming estimate of income and a production function estimate of income is that in the production function each resource is valued in determining the income, while in the linear programming estimate only those resources which are restrictive have a value in the model which generates the income. The non-restrictive resources have an opportunity cost of zero in the programming model. This is the more realistic approach in most instances. On most farms, surplus resources such as winter labor, and excess pasture are of no value. The production function approach has to place a value on these resources.

As was mentioned earlier, during the period of the study net income to farmers on a national level decreased rapidly. Farmers as a group were forced to make more drastic changes than usual in an effort to remain near the equilibrium point, because the changing economic conditions penalized farmers heavily for inefficiency. Even those farmers whose goal was merely an income above a fixed level and who had confortably exceeded the level for

several years found themselves in the position where they would have to change the basic organization of their farm if they were to continue to achieve their goal.

This study is an attempt to determine which of the two following alternatives has been the best method of combating the unfavorable economic conditions both from the point of view of the farmer, and from the point of view of society as a whole.

The first alternative has been either to increase the technological efficiency of production through applications of new methods or by increasing the efficiency of the old methods, or to increase the volume of production by adding new enterprises, increasing the size of old enterprises or by switching from one enterprise to another.

The second alternative has been to expand the size of the farm by increasing the acreage with or without the addition of more machinery and capital to the farm business. (The farms under consideration in this study retained their basic characteristics of a grain or grain-livestock farm. Highly specialized farms like a pig hatchery where the main source of income came from labor and capital rather than land and labor were not included in the sample.)

The hypotheses that were used in this study are:

1.) The observed change in actual income has been more favorable for those farms which increased in acreage than for those which did not.

2.) The difference in the deviation of the actual income from the optimal income between the beginning year and the final year was greater for the farms which increased in acreage than those with constant size.

For clarification of Hypothesis 2 the following sub-hypotheses will be considered:

2A.) The deviation of the actual income from the optimal income was greater in the final year than in the beginning year for the farms which increased in acreage.

2B.) The deviation of the actual income from the optimal income was less in the final year than the beginning year for those farms which had a constant acreage.

2C.) The deviation of the actual income from the optimal income were approximately equal during the initial year for both farms which increased in acreage and those which had constant acreage.

2D.) The deviation of the actual income from the optimal income in the final year was greater for those farms which increased in acreage than those with constant acreage.

Notation:

A^a = Farms that don't change size: actual income
A^o = Farms that don't change size: optimal income
B^a = Farms that change size: actual income
B^o = Farms that change size: optimal income
Subscript 1 refers to the beginning year and subscript 2 refers to the final year

Restatement of Hypotheses:

1. $B_1^a - B_2^a < A_1^a - A_2^a$

2. $(B_2^o - B_2^a) - (B_1^o - B_1^a) > (A_2^o - A_2^a) - (A_1^o - A_1^a)$

2A. $(B_2^o - B_2^a) > (B_1^o - B_1^a)$

2B. $(A_2^o - A_2^a) < A_1^o - A_1^a$

2C. $(B_1^o - B_1^a) \cong (A_1^o - A_1^a)$

2D. $(B_2^o - B_2^a) > (A_2^o - A_2^a)$

CHAPTER III. PROCEDURE

Sample Selection

The data used in the problem were obtained from Farm Bureau Farm Management record summary sheets from Central Illinois for the years 1951 and 1957. Seven counties were included in the study. These were Champaign, Douglas, DeWitt, Macon, Moultrie, Piatt, and Vermillion. These counties were selected in order to obtain a homogeneous sample with respect to land quality and type of farming area. The soil types in the area are predominantly Drummer clay loam and Flanagan silt loam. (20) Except for the northern portion of Vermillion county which has a slightly shorter growing season, the area has an average growing season of 170-180 frost-free days. The average annual rainfall of the area increases from south to north from 39 to 41 inches. (14) The area is distinctly a cash grain area, over 73 per cent of the farms in the seven counties being classified as cash grain farms in the 1954 agricultural census. Tenancy is relatively high throughout the area. More than 65 per cent of the land in each of the counties was operated by tenants in 1954. (18)

The year 1957 was selected because it was the most recent year for which data were available. The years 1951, 1952, and 1953 were the three most recent years when farm incomes were relatively high. Only a slight downward trend in income occurred during this period. The year 1951 was selected because the weather conditions and working conditions during the growing season were similar to those in 1957.

A list was obtained of all of the farms in the seven counties which had kept records in both the years 1951 and 1957. There were a total of 283

farms. In order to keep the sample homogeneous with respect to soil fertility, all farms with a soil productivity rating of under 75 were dropped. The farms were then examined with respect to land size. It was thought that decreases in acreages were probably due to one of three causes: (1) voluntary reduction of land size because of age or ill health, (2) the involuntary reduction in land size by a tenant who could not replace rented land he was no longer able to lease, or (3) the development of highly specialized enterprises which required large amounts of labor. Since the first two types of farms do not enter into the scope of the present problem and the third type would require a different type of program, farms which had decreased by more than 20 acres between 1951 and 1957 were rejected. The remaining farms were then divided into a group which had increased in acreage by more than 20 acres between 1951 and 1957 and a group which had not changed by more than 20 acres. Throughout the rest of the paper the latter group shall be called the constant acreage or A group. The former group will be called the B group.

Each of the two groups were then divided into four subgroups on the basis of available labor in 1951. The groupings were made on the basis of 1, 1 1/2, 2, and 3-or-more-man farms. The limits of the available labor for each size group are listed in Table 1. The available labor in 1957 was then investigated. If a farm were close to the limit of one group in one year and located in the adjacent group during the other year, it was put in the group which corresponded to the average of the years. If a farm's labor supplies for the two years were located in non-adjacent groups, the farm was dropped

from the sample in most instances in order to keep the sample groups as homogeneous as possible with respect to labor. The number of farms in each group is shown in Table 1. For identification purposes, the size groups will be numbered 1, 2, 3, and 4 according to ascending months of available labor. The total number of farms used in the sample was 185.

Table 1

NUMBER OF FARMS IN GROUPS A AND B, BY LABOR SIZE OF FARM: 1951 AND 1957

Months of Available Labor	Number of Farms with Constant Acreage (The A Group)	Number of Farms Which Increased in Acreage (The B Group)
9.0 - 14.9 (Labor Size Group 1)	37	22
15.0 - 20.9 (Labor Size Group 2)	36	17
21.0 - 26.9 (Labor Size Group 3)	20	23
More than 27 (Labor Size Group 4)	13	17

Mean values were obtained of variables measuring characteristics of each of the groups. These values are shown in Tables 2 and 3. Two measures of income are needed to test the hypotheses. The actual income figure was obtained from the Farm Bureau Farm Management record figure for unpaid labor, land, capital, and management plus the actual figure for hired labor expense. Hired labor expense was included in the actual income

figure since the labor restriction in the linear program model does not differentiate between hired and unpaid labor. The other measure or optimal income was the income generated by the farm organization determined by the linear programming model.

The linear programming model was an expectation model to derive the maximum profit for the coming year. The program was constructed to furnish what appeared to be the most profitable organization for the coming year from the farmer's viewpoint on January 1. The actual income was the profit experienced during the year.

Restrictions

The restrictions used in the program for 1951 are listed in Table 2 and those used for 1957 are listed in Table 3. The acreage restriction for each group was the mean of the acreage of the farms in each group.

Since the total amount of labor per year was computed in months, the yearly figure for each group of farms was multiplied by 250 to give the total number of hours per year. (Two hundred and fifty was selected as the number of hours available per month after studying the detailed labor records of an adjoining area which were obtained from a recent detailed cost study. Although individuals worked more than 250 hours per month, 750-800 was about the maximum in any 3 month period.) To determine the number of hours in any 3 month period, the hourly figure for size groups 1, 3 and 4 were divided by four. It was assumed that size group 2 (15 to 20.9 months of available labor) in most instances had either family labor which was more

Table 2

LEVELS OF THE RESTRICTIONS USED IN THE 1951 LINEAR PROGRAMMING TABLEAUS

Size Group Designation: Restriction	Restriction Levels (Po Column) 1A	1B	2A	2B	3A	3B	4A	4B
1. Acres of land	210	187	252	493	326	363	593	504
2. Hours of labor available during February, March, April	831	838	992	992	1475	1456	2344	2341
3. Hours of labor available during May, June, July	831	838	1233	1233	1475	1456	2344	2341
4. Hours of labor available during August, September, October	831	838	1233	1233	1475	1456	2344	2341
5. Hours of labor available during November, December, January	831	838	992	992	1475	1456	2344	2341
6. Corn transfer (in bushels)	0	0	0	0	0	0	0	0
7. Pasture transfer during July (in days)	0	0	0	0	0	0	0	0
8. Hay transfer (in tons)	0	0	0	0	0	0	0	0
9. Pasture + hay $\leq$ small grain	0	0	0	0	0	0	0	0

Table 3

LEVELS OF THE RESTRICTIONS USED IN THE 1957 LINEAR PROGRAMMING TABLEAUS

Size Group Designation: Restriction	Restriction Levels (Po column) 1A	1B	2A	2B	3A	3B	4A	4B
1. Acres of land	209	242	252	385	328	459	589	644
2. Hours of labor available during February, March, April	806	825	883	987	1362	1537	2012	2119
3. Hours of labor available during May, June, July	806	825	1017	1224	1362	1537	2012	2119
4. Hours of labor available during August, September, October	806	825	1017	1224	1362	1537	2012	2119
5. Hours of labor available during November, December, January	806	825	883	987	1362	1537	2012	2119
6. Corn transfer (in bushels)	0	0	0	0	0	0	0	0
7. Pasture transfer during July (in days)	0	0	0	0	0	0	0	0
8. Hay transfer (in tons)	0	0	0	0	0	0	0	0
9. Pasture + hay $\leq$ small grain	0	0	0	0	0	0	0	0
10. Wheat acreage	15	15	15	15	15	15	15	15

readily available in summer or hired labor which was hired at peak times during the cropping season. This group first had 3,000 hours of labor (12 months) subtracted from its means. One sixth of the remainder was then allotted to the February, April quarter, 1/3 to the May, July quarter, 1/3 to the August, October quarter, and 1/6 to the November, January quarter. The grouping of months was selected on the basis of the similarity and transferability of the cropping labor requirements during these 3 month periods.

The corn transfer restriction required all corn which was not fed to livestock to be sold during the year and therefore reflected no change in inventory from the previous year. Pasture disposal during July was used as a restriction since the month of July would be most restrictive during the summer. In earlier months pasture growth is heavier and stock requirements are lighter. In later months stubble could be used to provide additional pasture. Another restriction requires that the acreage in meadow be equal to or less than small grain acreage. This assumes that the meadow ground was in small grain the year before and that approximately the same amount of land was in small grain each year. This eliminates the possibility of second year meadow ground. This restriction is a realistic and necessary requirement for maximum profit on level highly productive soils except on very specialized livestock farms.

In 1957 the addition restriction of wheat $\leq$ 15 acres was added to make allowance for the government program. Since considerably more wheat was grown in each county than the wheat allotments, this meant that the 15

acres rather than the allotment was the limiting factor on many farms. When programming with means from groups of farms, 15 acres was the empirically relevant limit.

A corn allotment restriction was not used because complying with acreage allotments indicated a lower income level than not complying. Therefore, it was not necessary to include a corn allotment alternative in order to get the most profitable system unless a corn purchasing activity had been allowed.

Activities

Fourteen structural activities of which thirteen were production processes were considered in the program. The fourteenth structural activity was corn selling. Corn, soybeans, wheat, oats, pasture and hay were each considered as separate activities and not as rotations. This allowed the greatest flexibility in the program although the use of individual crops is not as realistic as the use of rotations. Since one of the assumptions of linear programming is that all the processes are independent, individual crops can not be used if the most profitable plan for several years is desired, unless allowance is made to change yield levels and fertilizer expense from year to year. Rotation activities can be constructed in a manner which will avoid this problem. However, the individual crop activity program will give a higher profit than a rotation activity program for any given year unless both solutions have the same crops in the same ratio.

Four beef activities and three hog activities were considered. No poultry or specialized crops were considered since to be profitable they would need either large amounts of capital and equipment or technical experience which is not available on most farms. The four beef enterprises considered were:

1. Roughage feeder calves. Four hundred fifty pound feeder calves purchased in October or November and wintered mainly on roughage. The calves are pastured through the summer without grain and full fed 90 days the following winter. The calves are then sold in the spring with a gain of 550 pounds.

2. Yearling steers. Six hundred pound yearlings purchased in April and pastured through the summer. They are full fed 90 days and sold the following spring with a gain of 500 pounds.

3. Full fed calves. Four hundred fifty pound calves purchased in April and full fed for 1 year, and sold the following spring with a 550 pound gain.

4. Two year old steers. Purchased in November at weight of 750 pounds. Full fed through winter and sold the following March with a gain of 300 pounds.

Beef cow herds were not considered in the program because they required large amounts of land which was more profitable in crop enterprises.

Three hog activities were also considered. The hog activities had different labor requirements during the different times of the year when labor might be slack. The three hog activities were:

1. A two-litter system, with sows farrowing in February and August. In 1951 there were 6.7 pig per litter, and 7.6 pigs per litter in 1957. Pigs were sold at a weight of 220 pounds during August and February.

2. A spring feeder pig system, with spring feeder pigs purchased during the month of April at a weight of 50 pounds, and sold at the weight of 220 pounds in August.

3. A fall feeder pig system, with fall feeder pigs purchased during the month of October at a weight of 50 pounds and sold at a weight of 220 pounds in January.

The only slack variable which was priced was corn. There was no corn buying activity, since labor during the cropping months is the limiting factor in livestock production and corn production is more than needed for feed on most farms in this area.

Data Sources for Estimating Coefficients

The coefficients (the amount of each restrictive element required per unit of a structural activity) used in the simplex tableau were obtained from several sources. An attempt was made to arrive at the most realistic estimates of the resource requirements for each activity. The 1951 coefficients were obtained mainly from Planning the Farm Business (13) and the Farm and Home Development Reference Book. (11) Yearly labor requirements were taken from Table 17 in the 1953 supplement to Planning the Farm Business. Monthly distribution of labor was obtained from Table 16 in the same source. Although some of the livestock activities in the program were not included, Table 16 was used as a guide. The 2 litter hog system labor cycle from this table was moved back one month so spring farrowing would occur in February before field work started and to obtain more favorable prices in the fall. Feed and hay requirements were obtained from Planning the Farm Business. Both feed and yearly labor requirements compared favorably with similar figures in the Detailed Cost Report for Central Illinois

1951 (1) (This study was taken in an adjacent area.)

The 1957 coefficients were obtained mainly from the Farm Management Manual. (7) Monthly labor requirements in per cent were the same as those used in 1951. An indirect labor figure was obtained from the Detailed Cost Report for Heavy Till Soils Central Illinois 1957 (2) and added to the direct labor figure. The 1957 feed and hay requirements were taken from the Farm Management Manual. Yearly labor and feed requirements were checked against the 1956 and 1957 detailed cost reports.

Determination of Crop Yields and Values of Activities

The yield of each of the cropping activities in each expectation model was determined by taking the average of the five previous years, with the exception that 1945 was substituted for 1947 in determining the 1951 yield because of the abnormal drouth of 1947. The price used for each crop was the average price for the previous year. The expected yield and price of oats, soybeans and wheat were multiplied together to give the expected value of the crop. The cash expenses were then subtracted to give the value per activity unit. Activity unit values are the returns to the limiting resources above cash costs.

Cost of producing the crops were obtained from the 1951 and 1956-57 detailed cost studies. For corn, soybeans, and oats the expenses deducted were power and machinery, annual fertilizers, depreciation on rotation fertilizers, soil improvement expenses, seed cost, crop expenses, interest

stored grain, and general farm expense. Wheat expenses were obtained similarly in 1951. However, the data were not available in the more recent cost studies, so estimates of the costs were obtained from the Farm Management Manual. The expense of an acre of hay or pasture was derived from the detailed cost studies, Illinois Farm and Home Reference Book, and the Farm Management Manual. Since corn, pasture, and hay were not given a price when computing the value of the activity units, the value of each of their activity units appears as a negative number in the tableau. This was the crop expense per acre. (Each of these activities had a corresponding transfer restriction which allocated the production among the other activities and the slack variables. Corn disposal was priced, but no value was given to surplus hay and pasture.)

The values of the beef activities were obtained in the following manner: a purchase price was derived from the price on January 1 of the year in question if the cattle were to be purchased in the following April. If the cattle were to have been purchased during the preceding fall, the actual price was used. An expected sale price was obtained from seasonal averages and outlook reports for the following year at the time when the cattle would be marketed. From the expected total value of the steers at sale time were deducted the purchase cost, the cost of protein, and the cost of producing beef per hundred pounds gain as obtained from the detailed cost studies for the appropriate year. This was the value given the beef activities per unit.

The values of the hog enterprises were obtained by deriving an expected price of hogs in the sale month from seasonal and outlook reports and multiplying this times the number of pounds per pig or per litter. The feeder pig price for a fifty-pound pig was obtained from the formula, 2 times the market price for 220-pound hogs at the time of purchase. One dollar was added to this because the pigs were purchased at the time when demand was the strongest. The feeder pig value was then subtracted from the sale value of the hogs. The value of the protein required for each pig activity and the cost of producing the pigs as obtained from the detailed cost studies of the appropriate year were then deducted to give the net value of each hog activity.

Table 4

1951 INITIAL SIMPLEX TABLEAU*

	C_j →		-25.64	42.26	21.44	28.12	-9.00	-17.57	103.34	128.95	122.29	91.93	399.51	20.28	15.52	1.51
		Resource or Activity Level	Corn	Soybeans	Oats	Wheat	Pasture	Hay	Steer Calves on Roughage	Yearling Steers	Drylot Steer Calves	2 yr. Old Steers	2 Litter System of Hog Production	Summer Feeder Pigs	Winter Feeder Pigs	Corn Disposal
C_i		P_o	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{19}
0	P_{14}		1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	P_{15}		1	1.4	.8	0	0	0	6	4.8	6	3.6	24	1.5	1	0
0	P_{16}		3.5	2.45	3.2	2	.5	4.1	3	2.4	6	0	10.2	2.6	0	0
0	P_{17}		3.0	2.10	0	3	1	3.42	3	2.4	6	0	14.6	.9	1	0
0	P_{18}		2.5	1.05	0	0	0	0	6	6	6	5.4	12	0	4	0
0	P_{19}		-57	0	0	0	0	0	35	54	60	38	235	13	16	1
0	P_{20}		0	0	0	0	-30	0	20	10	0	0	3	.6	0	0
0	P_{21}		0	0	0	0	0	-2.3	1.25	1.5	.8	.9	.15	0	.02	0
0	P_{22}		0	0	-1	-1	1	1	0	0	0	0	0	0	0	0
	Z_j	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	$Z_j - C_j$	0	25.64	-42.26	-21.44	-28.12	9.00	17.57	-103.34	-128.95	-122.29	-91.93	-399.51	-20.28	-15.52	-1.51

From Table 2.

*The unit matrix except for the corn disposal activity has been omitted because of space requirements.

Table 5

1957 INITIAL SIMPLEX TABLEAU*

C_i		C_j →		-25.64	43.50	19.66	47.45	-10.00	-20.00	105.39	106.38	129.39	80.50	302.56	14.01	10.22	1.35
		Resource or Activity Level		Corn	Soybeans	Oats	Wheat	Pasture	Hay	Steer Calves on Roughage	Yearling Steers	Drylot Steer Calves	2 yr. Old Steers	2 Litter System of Hog Production	Summer Feeder Pigs	Winter Feeder Pigs	Corn Disposal
			P_o	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{19}
0	P_{14}	From Table 3	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	P_{15}		.76	0	.8	0	0	0	3.9	3.2	3.9	2.4	19.2	.75	0	0	
0	P_{16}		2.69	2.6	3	1.8	.5	3.63	2.1	1.8	3.9	0	8.2	1.3	0	0	
0	P_{17}		2.30	3.9	0	2.8	1	2.97	2.1	1.8	3.9	0	10.4	.45	1.25	0	
0	P_{18}		1.92	0	0	0	0	0	3.9	3.9	3.9	3.6	9.6	0	1.75	0	
0	P_{19}		-63	0	0	0	0	0	35	46	55	40	210	10.5	12	1	
0	P_{20}		0	0	0	0	-30	0	20	10	0	0	3	.6	0	0	
0	P_{21}		0	0	0	0	0	-2.35	1.0	1.0	1.1	.7	.15	0	.02	0	
0	P_{22}		0	0	-1	-1	1	1	0	0	0	0	0	0	0	0	
0	P_{23}		0	0	0	1	0	0	0	0	0	0	0	0	0	0	
	Z_j		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	$Z_j - C_j$		0	25.64	-43.50	-19.66	-47.45	10.00	20.00	-105.39	-106.38	-129.39	-80.50	-302.56	-14.01	-10.22	-1.35

*The unit matrix except for the corn disposal activity has been omitted because of space requirements.

CHAPTER IV. CONCLUSIONS

Tests

Although statistical tests for significant differences between the actual income figures are well developed, there are no such tests available for use on the incomes generated by the linear programming optimal organizations. This is because there is no practical way of estimating the variance of these optimal income figures. As a result, it was impossible to test hypothesis 2 and the subhypotheses with the precision that was possible in the case of hypothesis 1.

Hypothesis 1 was tested by combining the standard errors of the difference of the means of the A farms and B farms in each labor size group and using the t test. The basis of the decision to accept or reject the other hypotheses were either the standard errors of the means of the actual incomes, or in some cases the standard errors of the differences of the means of the actual incomes. The hypotheses were first tested under the condition that the standard errors of the optimal incomes were equal to those of the corresponding actual incomes. The hypotheses were then tested again after giving the standard errors of the optimal incomes the value of zero. (The optimal incomes for the individual farms in each group are probably more closely clustered than the actual incomes and have a smaller variance. The variance of the actual incomes is probably greater than the maximum variance possible with the programs used in this problem.) Except for two small differences, the results of the tests were identical. A difference of more than twice the standard error term was regarded as significant. Under

the stated conditions, this was a t test with approximately a 95% confidence interval.

Tables

Table 6 contains the actual and optimal incomes and the standard errors of the means of the actual incomes by labor size groups for 1951 and 1957. Table 6 also contains the hired labor and the total available labor in months as well as the cost of hired labor for both years by labor size groups.

Tables 7 through 12 contain the computations necessary for testing the hypotheses. The column headings of these tables are in the abbreviated notation explained on page 7. Labor size group designations are on the left. The top half of the tables contain the actual and optimal income figures and the deviations mentioned in the hypothesis. The bottom half contains the appropriate standard error terms, the difference in the deviations (the quantity to be tested) and the t values. Table 7, for example, has in the top half going from left to right, the actual incomes in 1951 of the farms which increased in acreage, the actual incomes of these farms in 1957, the actual incomes in 1951 and 1957 of the farms with constant acreage and the decrease in actual income between 1951 and 1957 for the group which increased in acreage and the group with constant acreage. The bottom half contains the combined standard errors of the differences of the means of the A and B groups, the difference in the decrease in income between the A and B groups and the t values.

Table 6

ACTUAL AND OPTIMAL RETURNS, STANDARD ERRORS OF THE MEANS, TOTAL AND HIRED LABOR IN MONTHS AND HIRED LABOR COST, 1951 AND 1957

Size Group Designation	1951						1957					
	Actual Returns to Land, Labor, and Capital	Optimal Returns to Land, Labor and Capital	Standard Error of the Mean of Actual Returns	Hired Labor in Months	Total Labor in Months	Cost of Hired Labor	Actual Returns to Land, Labor and Capital	Optimal Returns to Land, Labor and Capital	Standard Error of the Mean of Actual Returns	Hired Labor in Months	Total Labor in Months	Cost of Hired Labor
1A	$10,874	$12,961	$590	.7	13.3	$132	$7,284	$12,827	$548	.8	12.9	$167
1B	9,964	11,817	772	1.0	13.4	140	8,800	14,779	915	1.4	13.2	299
2A	13,590	16,082	724	4.2	17.8	631	8,407	15,373	583	2.4	15.2	523
2B	14,595	18,290	1809	3.9	17.8	606	13,349	23,276	1632	5.5	17.7	1149
3A	18,062	20,640	1218	11.2	23.6	1829	12,603	19,923	1130	9.6	22.8	1763
3B	20,823	22,459	1487	9.9	23.3	1953	15,624	27,686	1370	10.3	24.6	2249
4A	27,746	36,591	3345	22.3	37.5	3893	20,896	35,424	3259	17.7	32.2	4210
4B	33,573	32,025	3416	21.2	37.3	3542	25,805	38,687	3034	18.6	33.9	4179

Table 7

COMPUTATIONS FOR TESTING HYPOTHESIS 1

Size Group Designations	B^a_{51}	B^a_{57}	A^a_{51}	A^a_{57}	$B^a_{51}-B^a_{57}$	$A^a_{51}-A^a_{57}$
			In Dollars			
1	9964	8800	10874	7284	1164	3590
2	14595	13349	13590	8407	1246	5183
3	20823	15624	18062	12503	5199	5559
4	33573	25805	27746	20896	7768	6850

	Standard Errors	Differences	t Values
1	980	2426*	2.48
2	1802	3937*	2.18
3	2333	360	.15
4	2702	-918	.34

*Significant Difference

Table 8

COMPUTATIONS FOR TESTING HYPOTHESIS 2A

Size Group Designations	B^o_{57}	B^a_{57}	B^o_{51}	B^a_{57}	$B^o_{57}-B^a_{57}$	$B^o_{51}-B^a_{51}$
			In Dollars			
1	14779	8800	11817	9964	5979	1853
2	23276	13349	18290	14595	9927	3695
3	27686	15624	22459	20823	12062	1636
4	38687	25805	32025	33573	12882	-1548

	Standard Errors		Differences	t Values	
1	892	1261	4126*	4.63	3.27
2	1184	1673	6232*	5.26	3.73
3	1905	2693	10426*	5.47	3.87
4	2222	3140	14430*	6.49	4.60

*Significant Difference

Table 9

COMPUTATIONS FOR TESTING HYPOTHESIS 2B

Size Group Designation	A^o_{57}	A^a_{57}	A^o_{51}	A^a_{51}	$A^o_{57}-A^a_{57}$	$A^o_{51}-A^o_{51}$
			In Dollars			
1	12827	7284	12961	10874	5543	2087
2	15373	8407	16082	13590	6966	2492
3	19923	12503	20640	18062	7429	2578
4	35424	20896	36591	27746	14528	8845
	Standard Errors		Differences		t Values	
1	405	567	3456*		8.53	6.10
2	1359	1922	4474*		3.29	2.33
3	1346	1904	4852*		3.60	2.55
4	1537	2173	5783*		3.76	2.66

*Significant Difference

Table 10

COMPUTATIONS FOR TESTING HYPOTHESIS 2C

Size Group Designation	B^o_{51}	B^a_{51}	A^o_{51}	A^a_{51}	$B^o_{51}-B^a_{51}$	$A^o_{51}-A^a_{51}$
			In Dollars			
1	11817	9964	12916	10874	1853	2087
2	18290	14595	16082	13590	3695	2492
3	22459	20823	20640	18062	1636	2578
4	32025	33573	36591	27746	-1548	8845
	Standard Errors		Differences		t Values	
1	972	1373	-234		.24	.17
2	1947	2755	1203		.62	.44
3	1922	2720	-942		.49	.35
4	4781	6759	-10393+		2.17	1.54

+Possibly Significant

Table 11

COMPUTATIONS FOR TESTING HYPOTHESIS 2D

Size Group Designations	B^o_{57}	B^a_{57}	A^o_{57}	A^a_{57}	$B^o_{57}-B^a_{57}$	$A^o_{57}-A^a_{57}$
			In Dollars			
1	14779	8800	12827	7284	5979	5543
2	23276	13349	15373	8407	9927	6966
3	27686	15624	19923	12503	12062	7420
4	38687	25805	35424	20896	12882	14528
	Standard Errors		Differences		t Values	
1	1066	1508	436		.41	.29
2	1733	2451	2861		1.65	1.17
3	1776	2511	4642+		2.61	1.85
4	4452	6298	-1634		.37	.26

+Possibly Significant

Table 12

COMPUTATIONS FOR TESTING HYPOTHESIS 2

Size Group Designation	$B^o_{57}-B^a_{57}$	$B^o_{51}-B^a_{51}$	$A^o_{57}-A^a_{57}$	$A^o_{51}-A^a_{51}$	$(B^o_{57}-B^a_{57})-(B^o_{51}-B^a_{51})$	$(A^o_{57}-A^a_{57})-(A^o_{51}-A^a_{51})$
			In Dollars			
1	5979	1853	5543	2087	4126	3456
2	9927	3695	6966	2492	6232	4474
3	12062	1636	7420	2578	10426	4842
4	12882	-1548	14528	8845	14430	5683
	Standard Errors		Differences		t Values	
1	980	1385	670		.68	.48
2	1802	2549	1758		.98	.69
3	2333	3303	5584+		2.39	1.69
4	2702	3823	8747*		3.24	2.29

+Possibly Significant
*Significant Difference

Tables 8 through 12 have two sets of standard error terms and two sets of t values. The term on the left is the appropriate estimate of standard error if the standard error of the optimal income is zero. The term on the right is the appropriate term if the standard error of the optimal income is equal to that of the actual income. As a result, there are also two t values. The standard error terms in Tables 7, 8, 9, and 12 are based on standard errors of the differences of the means. The standard error term in Tables 10 and 11 are based on standard errors of the means.

Hypothesis 1

The observed change in actual income was more favorable for those farms which increased in acreage between 1951 and 1957 than those which did not.

$$B^a_{51} - B^a_{57} < A^a_{51} - A^a_{57}$$

The computations in Table 7 indicate that the decrease in income between 1951 and 1957 was less for those farms which increased in acreage in labor size groups 1 and 2. However, there was no significant difference in the change in actual income for labor size groups 3 and 4. Hypothesis 1 was accepted for labor size groups 1 and 2 but rejected for labor size groups 3 and 4.

Hypothesis 2 A

The deviation of the actual income from the optimal income was greater in 1957 than in 1951 for the farms which increased in land size.

$$B^{o}_{57} - B^{a}_{57} > B^{o}_{51} - B^{a}_{51}$$

Table 8 shows the deviations of actual income from the linear programming optimal income to be significantly greater in 1957 than in 1951 in all labor size groups. There was a tendency for the t values to increase as the available labor increased, indicating a larger relative change in the deviation from the optimal income in the larger labor size groups.

Hypothesis 2 B

The deviation of the actual income from the optimal income was less in 1957 than in 1951 for those farms which had constant acreage.

$$A^{o}_{57} - A^{a}_{57} < A^{o}_{51} - A^{a}_{51}$$

Table 9 shows that in no labor size group was the deviation of the actual income from the optimal income smaller in 1957 than in 1951. Rather, all the deviations of all the labor size groups were significantly larger.

Hypothesis 2 C

The deviation of the actual income from the optimal income was approximately equal in 1951 for the farms which increased in land size and those which had constant acreage.

$$B^{o}_{51} - B^{a}_{51} \lesssim A^{o}_{51} - A^{a}_{51}$$

Table 10 shows no significant difference between the deviation of the incomes of the A and B groups from the optimal level except for size group 4. Hypothesis 2 C was accepted for labor size groups 1, 2, and 3 and rejected for 4. (Only one of the t values reflects a significant difference. However, there is a large difference in the t values of group 4 and the other groups).

Hypothesis 2 D

The deviation of the actual income from the optimal income in 1957 was greater for those farms which increased in acreage than those with constant acreage.

$$B^{o}_{57} - B^{a}_{57} > A^{o}_{57} - A^{a}_{57}$$

Table 11 shows that the only difference in the deviation from the optimal level of income which might be significant is that of labor size group 3. This is significant only when we consider the standard error of the optimal income to be zero. When the standard error of the optimal income is considered to be equal to that of the actual income, the significance level was substantially lower. As a result, hypothesis 2 D was rejected for all four size groups.

Hypothesis 2

The difference in the deviation of the actual income from the optimal income between 1951 and 1957 was greater for the farms which increased in acreage than those with constant acreage.

$$(B^{o}_{57} - B^{a}_{57}) - (B^{o}_{51} - B^{a}_{51}) > (A^{o}_{57} - A^{a}_{57}) - (A^{o}_{51} - A^{a}_{51})$$

The computations in Table 12 show that the difference in the deviations of the actual income from the optimal income increased as the available labor increased. The difference was significant in labor size group 4 and significant in labor size group 3 if the standard error of the optimal income is taken to be zero. Hypothesis 2 was accepted for labor size groups 3 and 4 and rejected for labor size groups 1 and 2.

Results by Size Groups

9.0 - 14.9 Months of Labor

The divergence of the actual income from the labor income was quite similar for both types of farms in this labor size group. However, the change in actual income was in favor of the group which increased in acreage. There was no significant change in the efficiency of organization. The increase in acreage at this labor level, therefore, had the effect of increasing income without changing the level of efficiency of organization.

15 - 20.9 Months of Labor

The decrease in actual income between 1951 and 1957 was significantly greater for the group with constant acreage. The change in the deviation from the optimal income level was similar for both the A and B groups. Table 12 indicates there was no significant difference in the efficiency of organization. An increase in acreage at this level of available labor, therefore, had the effect of increasing income with no effect on the efficiency of organization.

21.0 - 26.9 Months of Labor

There was no significant difference in the amount of change in income between 1951 and 1957 for farm groups A and B. The only possible significant difference in the deviation from the optimal income level was in 1957. The deviation of the B group was significantly larger if the smaller standard error term was used. However, since none of the other groups had large deviations, this was regarded as being due to chance and rejected. There was a considerable loss in the efficiency of organization which was regarded as probably significant since labor size group 4 had an even greater drop in the efficiency of organization. In this labor size group, farms in the B group made no gain in income relative to the A group while undergoing a drop in the efficiency of organization.

Over 27.0 Months of Labor

The B group of farms showed a decrease in actual income of $918 more than the A group. Although this difference is not large enough to be significant, it is of interest to compare it with the large positive values in the smaller labor groups and the small positive value for labor size group 3. Although there was a significant increase in the deviation of the actual income from the optimal income for both the A and B groups, the increase was substantially larger for the B group. The deviation of the A group from the optimal income was significantly larger than that of the B group in 1951. There was a significant difference in the amount of change of the actual income from the optimal income between 1951 and 1957 between the A and B

groups indicating that there was a substantial drop in the level of the efficiency of organization for the B group. In this labor size group there was no significant difference in the change between the A and B groups in actual incomes while the B group had a substantially lower level of efficiency in 1957.

Conclusions

Adding more land was a more effective way of maintaining income than the other methods used for those farms in this study which were operated with less than 2 full time men. In this labor size range there was no noticeable difference in efficiency between farms which increased in land size and those that did not.

However, the farms in the 3 and 4 labor size groups (Those with 2 or more full time men) which increased in land size, suffered a noticeable loss in efficiency of organization. Furthermore, there was no gain in actual income in 3 B when compared to 3 A and there was a loss (although not statistically significant) in 4 B when compared to 4 A. It is of interest to note in Table 6 that in all the B groups except 4 available labor in 1957 was almost exactly equal to that in 1951. Since the farms in 4 B had over 3 months less available labor and the increase in labor expense was twice as great as the next highest increase, a shortage of hired labor might be causing the big drop in both income and efficiency.

It appears that the average breaking point, at which it is no longer profitable for a grain farmer on highly productive soil with equipment and

labor similar to that available in this area of Central Illinois to add land, occurs when the total labor available is more than 2 full time men. If the criteria is the most efficient level of organization, the point at which it is no longer profitable to add land under these conditions is when the available labor supply is over 18 months. It will probably prove more profitable for those farms within these limits which can expand their land size to do so while farms with larger amounts of available labor can probably expand more profitably in other ways. It appears that a farm which has the labor of more than one man available during the winter months can profit more by increasing the livestock program. This employs the surplus labor more profitably than adding land which requires large amounts of labor at the time when labor is already the limiting factor.

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APPENDIX A

VALUES USED IN THE EXPECTATION MODEL

Table 13

COMPUTATION OF THE VALUE OF THE CROP ACTIVITY UNITS: 1951 AND 1957

1951	Corn	Soybeans	Oats	Wheat	Pasture	Hay
Expected yield[1]	57	26	42	26		2.3
Expected price[2]	1.51	2.35	.78	1.82		
Expected gross value per acre	[3]	61.10	32.76	47.32	[3]	[3]
Power and machinery expense	13.29	10.45	6.57	7.42		10.75
Soil improvement expense	6.97	1.84	1.45	7.03		2.16
Seed expense	1.60	3.38	1.94	3.76		1.76
Other crop expense	.85	.68	.15	.34		.01
General farm expense	2.93	2.49	1.21	.65		2.89
Total variable costs[4]	25.64	18.84	11.32	19.20	9.00[5]	17.57
Net value per activity unit (one acre)	-25.64	-42.26	21.44	28.12	-9.00	-17.57
1957						
Expected yield[6]	63	28	49	35		2.35
Expected price[7]	1.35	2.25	.67	1.97		
Expected gross value per acre	[3]	63.00	32.83	68.95	[3]	[3]
Power and machinery expense	15.17	10.03	7.12			
Fertilizer and soil improvement expense	6.12	2.38	2.33			
Seed expense	1.92	2.64	2.00			
Other expense	1.23	1.00	.21			
General farm expense	3.31	2.55	1.51			
Total variable costs[8]	27.75	19.50	13.17	21.50[9]	20.00[10]	10.00[10]
Net value per activity unit (one acre)	-27.75	43.50	19.66	47.45	-20.00	-10.00

Table 13 (continued)

[1]The mean of the county averages for the five years, 1945-1946 and 1948-1950. Data Source: Illinois Agricultural Statistics.

[2]The average price for the seven counties for the year 1950. Source: Illinois Agricultural Statistics.

[3]Not computed because the production of corn, pasture, and hay is allocated to the other activities for disposal.

[4]Source: Detailed Cost Report for Central Illinois, 1951 (1), pp. 14-20.

[5]Estimated from hay expenses for 1951. (1), p. 20.

[6]The mean of the county averages for the five years 1952-1956. Data Source: Illinois Agricultural Statistics.

[7]The average price for the seven counties for the year 1956. Source: Illinois Agriculture Statistics .

[8]Source: Detailed Cost Report for Heavy Till Soils Central Illinois, 1957, (2).

[9]Source: Farm Management Manual (7), p. 3. Fertilizer expense was estimated and added to the direct crop cost obtained from page 3.

[10]Estimated from relevant expenses in (2) and (7).

Table 14

COMPUTATION OF THE VALUE OF THE BEEF ACTIVITY UNITS
1951 AND 1957

1951	Roughage Fed Calves	Dry Lot Fed Calves	Yearling Steers	2 Year Old Steers
Sale price per hundred[1]	$30.68	$33.43	$30.68	$30.68
Sale weight	1000 lb	1000 lb	1100 lb	1050 lb
Sale value	$306.80	$334.30	$337.48	$322.14
Purchase price per hundred[2]	$33.10	$35.00	$27.47	$27.08
Purchase weight	450 lb	450 lb	600 lb	750 lb
Purchase cost	$148.95	$157.50	$164.82	$203.10
Cost of Protein Supplement[3] $4.43 per hundred[4]	$8.86	$8.86	$2.21	$2.21
Expenses ($8.30 per hundred pounds of gain)[5]	$45.65	$45.65	$41.50	$24.90
Net value per activity unit (one animal)	$103.34	$122.29	$128.95	$91.93
1957				
Sale price per hundred[1]	$22.30	$25.45	$22.30	$22.30
Sale weight	1000 lb	1000 lb	1100 lb	1050 lb
Sale value	$223.00	$254.50	$245.30	$234.15
Purchase price per hundred[2]	$19.25	$20.50	$18.46	$17.96
Purchase weight	450 lb	450 lb	600 lb	750 lb
Purchase cost	$86.83	$92.25	$110.76	$134.70
Cost of Protein Supplement[6] $3.43 per hundred[7]	$7.55	$9.43	$6.86	$6.17
Expenses ($4.26 per hundred pounds of gain)[8]	$23.43	$23.43	$21.30	$12.78
Net value activity unit (one animal)	$105.39	$129.39	$106.38	$80.50

Table 14 (Continued)

[1]Expected price based on previous year's prices and market outlook. Sources: Livestock and Meat Statistics 1957, USDA, Agricultural Marketing Service, Washington, D.C., pp. 213-220. The Livestock and Meat Situation, USDA, Agricultural Marketing Service.

[2]Actual price. Source: Livestock and Meat Statistics 1957.

[3]Amounts of proetin supplement needed per animal unit were obtained from Planning the Farm Business (13), p. 20.

[4]Average cost of soybean oil meal in 1951. Source: The Feed Situation, USDA, Agricultural Marketing Service.

[5]Detailed Cost Report for Central Illinois (1), p. 24.

[6]Amounts of protein supplement needed per animal unit were obtained from Farm Management Manual (7), p. 10.

[7]Average cost of soybean meal during 1957. Source: The Feed Situation.

[8]Detailed Cost Report for Heavy Till Soils Central Illinois, 1957 (2), p. 24.

Table 15

COMPUTATION OF THE VALUE OF THE HOG ACTIVITY UNITS 1951 AND 1957

1951	2 litter system	spring feeder pigs	fall feeder pigs
Amount sold in August	1475 lb.	220 lb.	-----
Price per 100 lb. in August [1]	$20.00	$20.00	-----
Amount sold in February	1475 lb.	-----	220 lb.
Price per 100 lb. in February	$18.20	-----	$18.20
Sale value	$ 549.95	$44.00	$40.04
Purchase cost [2]	-----	$15.56	$15.56
Cost of protein supplement [3] ($4.43 per 100 lb.) [4]	$47.49	$2.21	$3.01
Expenses ($3.49 per 100 lb.) [5]	$102.95	$5.95	$5.95
Net value per activity unit	$399.51	$20.28	$15.52
1957			
Amount sold in August	1550 lb.	220 lb.	-----
Price per 100 lb. in August [1]	$15.78	$15.78	-----
Amount sold in February	1575 lb.	-----	220 lb.
Price per 100 lb. in February [1]	$14.35	-----	$14.35
Sale value	$470.60	$34.72	$31.57
Purchase cost [2]	-----	$12.48	$12.48
Cost of protein supplement [6] ($4.07 per 100 lb.) [7]	$60.00	$2.40	$3.04
Expenses ($3.43 per 100 lb.) [8]	$108.04	$5.83	$5.83
Net value per activity unit	$302.56 (2 litters)	$14.01 (1 pig)	$10.22 (1 pig)

[1] Estimated price based on previous years price and outlook reports. Source: Livestock and Meat Statistics 1957 and The Livestock and Meat Situation.

[2] These were derived from a formula for feeder pig prices obtained from Dr. A. G. Mueller of Department of Agricultural Economics at the University of Illinois. (Two times the current market price for hogs). One dollar was added to this price because the hogs were purchased at the time when demand was highest.

Table 15 (Continued)

[3]Amounts of protein supplement needed were obtained from Planning the Farm Business (13), p. 20.

[4]Average cost of soybean oil meal in 1951. Source: The Feed Situation.

[5]Detailed Cost Report for Central Illinois 1951, p. 21.

[6]Amount of protein supplement needed per animal unit obtained from Farm Management Manual (7), p. 10.

[7]Average cost of soybean oil meal in 1957. Source: The Feed Situation.

[8]Detailed Cost Report for Heavy Till Soils Central Illinois 1957 (2), p. 21.

APPENDIX B

THE LINEAR PROGRAMMING OPTIMAL ORGANIZATIONS

The simplex solutions to the linear programming problems were obtained on the high speed digital computer, the Illiac, of the University of Illinois Graduate College; Library routine M15-183 was used. Machine time required was approximately four minutes for each program. Six iterations were necessary to arrive at the optimal solution in 1951 and seven iterations were necessary in 1957. The same activities entered into the optimal solutions for both the farms which increased in acreage and those with constant acreage.

The structural activities replaced restrictions in the following order during the 1951 iterations.

1. Corn production replaced the acreage restriction.
2. Roughage fed steer calves replaced the pasture transfer restriction.
3. The 2 litter hog system replaced the roughage fed steer calves.
4. Pasture production replaced the hay transfer restriction.
5. Hay production replaced the restriction requiring meadow to be less than or equal to small grain.
6. Wheat production replaced spring or summer labor.

Changes in the level of resources or activities in the P_0 column occurred only after the first iteration and the last iteration. (Hog production could not be carried on at a positive level until pasture and hay were produced. Pasture and hay could not be produced until wheat was produced). Activity

and resource levels in the final organization, the final $Z_j - C_j$ of interest, and the total returns to the organization after the first and sixth iterations are included in Table 16.

The structural activities replaced restrictions in the following order during the 1957 iterations.

1. Corn production replaced the acreage restriction.
2. Roughage fed steer calves replaced the pasture restriction.
3. The dry lot fed steer calves replaced the hay transfer restriction.
4. Hay production replaced the restriction requiring meadow to be less than or equal to small grain.
5. Wheat production replaced the restriction on wheat acreage.
6. The 2 litter system of hog production replaced roughage fed feeder steers.
7. Pasture production replaced summer or fall labor.

Table 17 includes the final organizations, $Z_j - C_j$ of interest and the total returns to the farm organization after the first, fifth, and final iteration.

At first glance the optimal solutions for 1951 and 1957 seem to indicate that straight cash grain farming is not as favorable as it once was compared to livestock farming. More acres of land are devoted to hay and pasture in 1957 in every labor size group. Furthermore the highest $Z_j - C_j$ for oats is only \$2.48 in 1957 and the lowest is \$7.60 in 1951. (The value of the $Z_j - C_j$ for activities which do not enter into the organization, is equal to the amount total returns would be reduced if a unit of the activity was forced into the program under the present organization.) Thus a small change in the

price of oats or a livestock enterprise would seem to change the organization and include more oats, meadow and livestock. However, the difference in returns between the organization from the first iteration (an all corn system) and the final organization was greater in 1951 than in 1957 although the final organization in 1957 contained more meadow and livestock indicating that a larger percentage of income is due to grain production in 1957 than 1951.

Returns to an hour of labor in the restrictive quarter dropped sharply from the low $Z_j - C_j$ of \$1.15 in 1951 to a high $Z_j - C_j$ of \$.12 in 1957. These low returns to labor indicate that an increase in the labor supply would not have increased returns much during 1957 on an optimally organized farm.

The livestock enterprise most suited for farms with these restrictions was the two litter hog system in 1951 and dry lot fed steer calves in 1957. The 2 litter hog system entered the 1957 program, sometimes at a high level but never increased net returns by more than \$40.

If a more refined program had been used it is doubtful if the organization of the farms would have been changed much. Soybeans had large final $Z_j - C_j$'s and are close labor substitutes for corn. It appears that if soybeans had been forced into the cropping system, income would drop by the value of the final $Z_j - C_j$ for each acre of soybeans and very little increase in income would come from increases in livestock enterprises.

Oats had small final $Z_j - C_j$'s in most cases in 1957 but had labor requirements that were even higher than corn in the restrictive months.

However, raising oats would have allowed more hay and pasture acreage. This would have allowed either fall feeder pigs or 2 year old steers to come into most of the programs which were short of labor in spring or summer and probably spring feeder pigs in those programs which were short of fall labor. If some oats had been forced into the 1957 programs then, it appears that the income from these organizations would be almost as high as from the optimal organizations.

Table 16

OPTIMAL ORGANIZATION AND $Z_j - C_j$ OF INTEREST BY LABOR SIZE GROUPS, 1951

Resource and Activity Levels	Size Group Designation							
	1A	1B	2A	2B	3A	3B	4A	4B
Acres of corn	206.7	180.7	241.7	285.9	314.6	356.7	583.8	485
Acres of wheat	1.6	3.1	5.1	3.5	5.7	3.1	4.6	9.5
Acres of hay	.6	1.2	2.0	1.4	2.2	1.2	1.8	3.7
Acres of pasture	1.0	1.9	3.1	2.1	3.4	1.9	2.7	5.7
Number of sows - (2-litters)	9.9	18.9	31.2	21.4	34.4	19.1	27.7	57.5
Corn selling in bushels	9456	5853	6428	11266	9837	15832	26769	14143
Spring labor disposal	387	202	0	192	334	640	1095	576
Summer labor disposal	0	0	48	0	.1	0	0	20
Fall labor disposal	58	4	25	45	0	91	165	0
Winter labor disposal	302	158	12	20	275	334	551	438
Income level from optimal organization	12961	11817	16082	18290	20640	22459	36591	32025
Income level after the first iteration	12690	11300	15228	17706	19700	21936	35835	30457
$Z_j - C_j$ of Interest.	Size groups (1A, 1B, 2B, 3B, 4A)					(3A, 4B)		(2A)
Land per acre			50.57			54.75		59.27
Soybeans			15.21			16.47		18.63
Oats			10.06			10.05		7.60
Spring labor			0			0		1.15
Summer labor			2.82			0		0
Fall labor			0			1.89		0
2 year old steers			7.62			8.93		11.86
Spring feeder pigs			8.45			3.01		3.07

Table 17

OPTIMAL ORGANIZATION AND $Z_j - C_j$ OF INTEREST BY LABOR SIZE GROUPS, 1957

Resource and Activity Levels	Size Group Designation							
	1A	1B	2A	2B	3A	3B	4A	4B
Acres of corn	179	212	222	355	297	429	559	614
Acres of wheat	15	15	15	15	15	15	15	15
Acres of hay	13.2	14.25	14.3	14	9.7	12.3	10.4	11
Acres of pasture	1.8	.7	.7	1	5.2	2.7	4.6	4
Number of sows (2 litters)	18.1	7.4	7.1	9.6	52.6	27.1	46.3	40
Number of dry lot fed calves	25.7	29.5	29.6	28.7	13.6	22.6	15.8	18
Corn selling in bushels	6062	10181	10867	18771	6973	20101	24626	29289
Spring labor disposal	222	407	429	421	72	603	637	813
Summer labor disposal	0	0	0	0	11	0	0	0
Fall labor disposal	23	60	65	111	0	99	106	141
Winter labor disposal	188	232	240	101	232	365	433	485
Income level from optimal organization	12827	14779	15373	23277	19923	27686	35424	38687
Income level after the fifth iteration	12813	14773	15368	23269	19883	27666	35389	38657
Income level after the first iteration	12417	14377	14971	22873	19486	27269	34992	38260

$Z_j - C_j$ of Interest.	Size groups 1A-2B and 3B-4B	3A
Land per acre	59.10	59.21
Soybeans	15.90	16.05
Oats	2.48	1.94
Summer labor	.12	0
Fall labor	0	.09
2 year old steers	8.30	8.38
Spring feeder pigs	2.45	2.34
Wheat per acre	25.45	25.61