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RESOURCE PRODUCTIVITY AND RETURNS IN APPLE AND TART CHERRY PRODUCTION ON MICHIGAN FRUIT FARMS

by

Arthur Franklin Bordeaux, Jr.

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ABSTRACT

RESOURCE PRODUCTIVITY AND RETURNS IN
APPLE AND TART CHERRY PRODUCTION
ON MICHIGAN FRUIT FARMS

By

Arthur Franklin Bordeaux, Jr.

The primary objectives of this study were: (1) To obtain benchmark data on labor and machinery use in apple and tart cherry production on Michigan fruit farms; (2) To evaluate the productivity of resources used in apple and tart cherry production enterprises on Michigan fruit farms, and; (3) To evaluate the impact of adopting newer technologies on the use of labor and capital in these enterprises.

A field questionnaire was used in twenty Western Michigan counties to obtain data from 258 fruit growers concerning their 1966 production practices. Analysis of the practices currently used indicated that apple and tart cherry producers had adopted tested labor saving techniques of production at moderately fast rates although large concentrations of labor use occurred in the harvesting operation. The absence of labor saving mechanical aids was most evident in this phase of the apple production process. Approximately one-fourth of the tart cherry producers had adopted mechanical harvesters to reduce the large labor requirements in

the harvesting operation.

Resource productivity in apple and tart cherry production was examined through production function analysis using Cobb-Douglas type production functions. Equations were fitted at the enterprise level and for two major operations within the enterprise, i.e., pruning and harvesting. Among the independent variables that were used, hours of machinery use, trees, and hired labor were found to have the greatest explanatory power.

Isoquant relationships between hired labor and machinery use indicated substantial increases in machinery use accompanied by decreases in hired labor use to reach the least cost combination of the two resources for: the enterprise, harvest, and pruning operation production functions in apple production; and the enterprise and harvest operation functions in tart cherry production.

Partial budgeting was used to evaluate the potential for adjustments in the combinations of machinery and hired labor inputs used in apple production. Production costs and returns were computed for two sets of production techniques with two basic farm situations of 25 and 70 acres of apple orchard and two basic wage levels of $1.50 and $2.00 per hour.

It was concluded that a farmer with 25 acres of apple orchard could not profitably adopt the advanced production techniques including the mechanical harvester if he operated the harvester only on his own acreage due to the high fixed costs associated with the mechanical harvester and reduced prices assumed for mechanically harvested apples.

Similarly, the farmer with 70 acres of apple orchard could not profitably adopt the advanced production techniques if he operated the harvester only on his own acreage. However, advanced production techniques were only slightly less profitable than standard production techniques after allocating only one-half of the depreciation and interest cost of the mechanical harvester to apple harvesting on the assumption that it would be used for multiple fruit crop harvest.

Partial budgeting was also used to evaluate the production costs and returns from tart cherry production using two alternative sets of production techniques and two basic wage levels of $1.50 and $2.00 per hour with 35 acres of bearing cherry orchard. Adoption of advanced production techniques, foremost of which is the mechanical cherry harvester, provided the grower with a higher net revenue per acre which increased relative to that from standard production techniques as wage levels rose.

Reduction of labor use in apple and tart cherry production appeared to have the greatest potential in the harvesting operation. Given the large quantities of labor that have traditionally been used in apple and tart cherry harvesting, a sharp reduction in labor use in these fruits due to harvest mechanization will reduce the over-all summer employment opportunities available in Michigan agriculture. The attraction of nearly continuous employment in a small geographic area for large numbers of migrant laborers from June to October will diminish, and disruption of the traditional seasonal pattern of employment in fruit harvesting will affect growers of other fruits. This may bring increased pressure for labor saving mechanization in the production of other fruits if labor becomes more expensive and difficult to obtain.

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CHAPTER I

INTRODUCTION

The Problem

Michigan farmers have historically had a prominent role in the production of several fruit commodities. The 1966 Michigan fruit crop was valued at 62 million dollars at the farm level. In terms of importance in total United States production, Michigan farmers had the following rankings in 1966: Tart cherries, first with fifteen million dollars production; Plums, second with one million dollars production; Apples, third with twenty-five million dollars production; Pears and grapes, fourth with two million and four million dollars production, respectively.[1]

Michigan farmers have been forced to make adjustments to keep production costs as low as possible in recent years in the face of rising labor costs. Several factors which have influenced the total supply and cost of labor are discussed in the following paragraphs.

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[1]Michigan Department of Agriculture, Michigan Agricultural Statistics, (Lansing, Michigan, September 1967), p. 8 and p. 16.

Low Labor Productivity

American farmers have traditionally been very successful in adopting new production techniques which have reduced the labor input per unit of output with each successive decade. The relative proportions of land, labor, and capital used in agricultural production have been shifting continually with the labor proportion decreasing while capital increased. Heady estimates that the percentages of agricultural inputs represented by land, labor, and capital were 8.7 percent, 74.6 percent, and 16.7 percent, respectively, of total inputs in the year 1910. By 1960 percentages for land, labor, and capital were 8.5 percent, 30.1 percent and 61.4 percent, respectively.[2] While land has remained relatively constant there has been a large decrease in labor relative to capital in the proportion of total inputs. The producers of certain crops have not benefitted from this general technological advancement to the extent that producers of other crops have.

The index of farm production per man hour for fruits and nuts in Table 1.1 indicates that the index for fruits and nuts has shown the smallest increase in the last ten years of any category of crops, with an increase to an index of 109 in 1967 from an index of 100 in 1957-59. In contrast, the most dramatic change was in feed grains where the index moved from 100 in 1957-59 to 218 in 1967.

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[2]Earl O. Heady and Edwin W. Haroldsen, Iowa Farm Science, March 1964, p. 4, quoted in Ross B. Talbot and Don F. Hadwiger, The Policy Process in American Agriculture (San Francisco: Chandler Publishing Company, 1968) p. 58.

Table 1.1 -- Index Numbers of Farm Production per Man-Hour, by Groups of Enterprises, United States Selected Periods and Years, 1910-67
(1957-59 = 100)

Year	Farm output	Crops									
		All	Feed grains	Hay & forage	Food grains	Vege-tables	Fruits & Nuts	Sugar Crops	Cotton	Tobacco	Oil Crops
1910-14	24	24	14	31	14	38	43	27	25	68	16
1920-24	26	27	16	32	15	40	51	26	23	65	15
1930-34	29	28	17	30	21	42	57	30	27	64	14
1940-44	41	41	25	42	32	49	73	36	37	70	26
1950-54	67	67	55	78	56	74	94	64	63	84	65
1955	80	77	67	83	67	85	103	77	81	94	76
1956	86	83	75	87	72	92	103	85	84	100	86
1957	91	90	86	92	82	95	96	96	91	96	90
1958	103	105	101	102	113	100	101	97	101	102	106
1959	106	105	113	106	105	105	103	107	108	102	104
1960	115	114	125	112	125	107	99	113	116	108	109
1961	120	116	139	116	115	112	100	117	125	110	117
1962	127	122	154	118	120	112	105	119	149	117	120
1963	137	129	160	120	120	116	102	140	160	121	121
1964	142	132	170	123	131	115	101	129	180	124	116
1965	154	146	198	127	134	120	105	128	209	118	130
1966	159	150	200	129	139	120	108	132	211	121	132
1967	169	155	218	131	133	120	109	133	214	125	131

Source: U. S. Department of Agriculture, Changes in Farm Production and Efficiency--A Summary Report 1968, Statistical Bulletin No. 233 (Washington, D. C.: Government Printing Office, 1968), Table 19, p. 15.

The slow increase in labor productivity in fruits is largely a result of the failure to mechanize the harvest operation which requires the largest labor inputs in fruit production. Many of the other operations such as pruning, tillage, and spraying have undergone increasing mechanization in recent years.

The characteristics of fruit crops are such that the harvest operations have not been easily mechanized. The raw product usually is quite susceptible to damage which inhibits fresh market sales of mechanically harvested products. In addition, multiple harvests during the season are often required due to uneven maturation of the fruit. Mechanical devices which would effectively discriminate between mature and immature fruit have been so expensive that they have not been economically feasible. As a result, the mechanization of fruit production has proceeded rather slowly with the exception of a few crops that are less easily damaged and can be effectively harvested in a once-over harvest operation. Without major changes in the harvest techniques which presently require large quantities of labor, the production per man hour will continue to increase at a relatively slower pace than most other crops.

Institutional Changes Affecting Total Supply and Cost of Labor

Legislation of various types emerging from the Michigan Legislature and the United States Congress has affected both the supply of labor available to the farmer and the cost of the labor which is available. The high dependence of fruit farmers on harvest labor in large quantities on a seasonal basis has made the impact of this legislation on the fruit farmers quite heavy.

Total Supply

The refusal of the United States Congress to extend Public Law 78 (the Bracero Program) beyond December 31, 1964 terminated a supply of workers formerly available to Michigan fruit growers. In 1964, for example, there were 12,843 foreign workers employed as seasonal agricultural workers at the peak period of employment of August 15.[3] This amounted to ten percent of the total seasonal work force during that period. These workers were primarily used in the harvest of pickle cucumbers and were not used in the harvest of apples or tart cherries. Removal of these workers from the seasonal work force affected the supply of workers available for apple and tart cherry harvest through increased competition for the remaining supply of workers. The termination of Public Law 78 also intensified Michigan's competition for domestic migrants with other states which had used nondomestic migrant workers.

In conjunction with the expiration of Public Law 78, greater restrictions were placed on the Immigration and Nationality Act (Public Law 414) in 1965. This prevented an expansion of the labor supply on a short-term basis through the use of foreign nationals from areas such as the British West Indies.

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[3]Michigan Employment Security Commission, Michigan Farm Labor Report-Post Season 1964, (Detroit, Michigan, 1964) p. 11.

Factors That Affected the Cost of Labor

Farm workers have been excepted from most major social legislation until recent years. Although worker protection and income maintenance programs were enacted in the 1930's, farm workers have only recently come under minimum wage provisions.

The Michigan legislature passed the Minimum Wage Act of 1964 which included agricultural workers under its provisions effective January 1, 1965. Fruit growers and other agricultural employers who normally paid piece-rate wages were exempted until July 31, 1966 when standards were to be established for minimum piece-rate wages. The minimum rates were $1.00 per hour in 1965, $1.15 per hour in 1966, and $1.25 per hour in 1967. Certain exceptions were made for members of the farm family and workers working less than thirteen weeks.[4]

Michigan enacted a workmen's compensation act covering farmers employing three or more persons which went into effect on May 1, 1967.[5] Michigan Public Act 289 of 1965 set forth rules and regulations pertaining to minimum conditions for housing to be supplied for migrant laborers by employers.

The Federal Fair Labor Standards Act was amended to include certain agricultural workers under its minimum wage provisions effective

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[4]Daniel W. Sturt, "Michigan's Minimum Wage Act of 1964, as Amended, and Farm Employers," (East Lansing, Michigan, Rural Manpower Center, Michigan State University) December 1966, pp. 1-3.

[5]Daniel W. Sturt, "Workmen's Compensation and Michigan Farm Employers," (East Lansing, Michigan, Rural Manpower Center, Michigan State University) May 1967, pp. 1-4.

February 1, 1967.

Low Unemployment and Rising Gross National Product

The national economic situation of the 1960's has been marked by an increasing Gross National Product and falling levels of unemployment. The Gross National Product has risen from 497.2 billion dollars in 1961 to 669.3 billion dollars (constant 1958 dollars) in 1967 (Table 1.2). At the same time the percent of the labor force unemployed decreased in every year except 1963 from a level of 6.7 percent in 1961 to 3.8 percent in 1967 (Table 1.2). These national economic conditions have intensified the pressures of increasing wages and scarce labor for farmers. The availability of nonagricultural jobs has increased the expense and difficulty of hiring farm laborers.

Table 1.2 Gross National Product and Unemployment Rates For Selected Years

Year	Gross National Product (billions of dollars)[a]	Unemployment (percent)[b]
1961	497.2	6.7
1962	529.8	5.5
1963	551.0	5.7
1964	581.1	5.2
1965	616.7	4.5
1966	652.6	3.8
1967	669.3	3.8

[a]Constant 1958 dollars.
[b]Unemployment of persons 16 years and over.

Source: Handbook of Labor Statistics 1968 - Bulletin No. 1600, U. S. Department of Labor, Washington, D. C., 1968, Table 49, p. 94 and Table 150, p. 343.

All of these factors have increased the minimum cost of labor to fruit farmers. It is evident thus, that in recent years the fruit farmer has been under increasing pressure to reduce his labor use as much as possible. If he reduces his labor use, the farmer must increase the quantity of other inputs in order to maintain production at or above previous levels. This increase in inputs usually comes in the form of substitution of machinery capital for hired labor. Therefore, in order to respond to the increasing cost of labor through a reduction in labor inputs, the farmer must have an acceptable machinery input to substitute. The adoption of such machinery inputs often involves reorganization of several operations in the production process. Mechanical harvesting may require changes in the pruning and tillage operations in order to be successful. The decision to adopt a new production technique is not an easy decision to make in many instances.

Objectives

The primary objective of this study is to evaluate the productivity of resources at the enterprise level for apple and tart cherry production on Michigan fruit farms. Apple and tart cherries are the two largest revenue producing tree fruits with twenty-five million and fifteen million dollars value of production at the farm level, respectively in 1966. The analysis will include reporting the use of labor and equipment in the operations performed on these two crops with production functions fitted at the enterprise level. In addition, the impact of adoption of advanced technology upon these enterprises will be examined.

More specifically the objectives are:

1. To report the observed use of labor and machinery in the production of apples and cherries with analysis of the differences observed between farms in the use of machinery and labor.
2. To develop production functions to statistically explain the production relationships observed for apples and cherries, with emphasis on the marginal value products and marginal rates of substitution for the factors of production.
3. To evaluate the impact of adopting newer production technologies on the use of labor and capital in these enterprises through the use of partial budgeting techniques.

Procedure

In order to determine the extent to which adjustments in labor and machinery use were possible in the production of apples and cherries, it was necessary to first ascertain the current use of factors of production in apple and cherry production. In order to accomplish this, a field questionnaire was designed to obtain data from fruit growers on current production practices and levels of labor use on their farms.

The basic sample on which the questionnaire was administered was determined by the Statistical Reporting Service of the United States

Department of Agriculture. The sample was drawn from twenty Western Michigan counties on an area sample basis. Additional large farms in each county were included in the sample on the basis of information obtained from county agents and horticulture agents.

Data were collected on volume of production by commodity, tree stock size, age of orchards and percentage of fruit sold for fresh and processed markets for each fruit on the farm. Labor use during the year for the total farm by type of worker (family, regular hired, or piecework) was also recorded. The amount of custom work hired or performed for others was also determined. An inventory of machinery and equipment used in fruit production was completed for the farm. Additional information on recent changes in farm organization and anticipated changes was enumerated as well as the amount of off-farm work the operator engaged in during the year.

For one or more crops on each farm detailed production data were obtained on the production operations performed during the 1966 production period. This included information on type and amount of labor and associated equipment used in the operations performed through removal of the fruit from the field. These detailed data were used as the basis for the apple and cherry production function analysis in conjunction with machinery values determined from the machinery inventory section. Production functions were developed at the enterprise level and for operations within the enterprise where possible.

The data which were used for the production functions were used in conjunction with data obtained from other sources in developing partial budgets to illustrate the potential reduction in labor use through adoption of advanced production techniques.

CHAPTER II

PRODUCTION PRACTICES USED IN APPLE AND TART CHERRY PRODUCTION

The data which were used to develop the production functions were obtained from the sample of 258 farms mentioned in Chapter I. A description of the data which were used in the production functions is presented in this Chapter.

The data obtained for apples and tart cherries consisted of inputs of labor and machinery used in the operations incurred in the production of the respective fruit in 1966. The data were limited to reasonably homogeneous blocks of bearing apple or tart cherry orchard.

Seventy-seven usable apple schedules were obtained in the combined Area Farm sample and Large Farm sample. Sixty-eight usable tart cherry schedules were also obtained. The production practices which were observed for apples and tart cherries are described for each fruit along with average quantities of resources used in production. The operations performed in the production of tree fruits are divided into five major categories for purposes of analysis. The five categories are: pruning, tillage, spraying, harvesting, and miscellaneous.

Practices Used in Apple Production

The standard apple tree grows to be a rather large tree and with proper pruning will have a productive life in excess of forty years. Some of the older orchards have trees on forty feet by forty feet spacings with twenty-five trees per acre. An average of forty trees per acre was observed for the sample farms. This large tree size influences the labor required to perform pruning and harvest operations on the trees. This has encouraged planting of dwarf and semi-dwarf trees in some instances. The incidence of bearing dwarf apple trees in the sample was so low that it was not possible to perform separate analysis for dwarf trees.

The farmer was asked to give an estimate of the age of the orchard on which the production data were obtained. The average of these estimates was 29 years. It is difficult to obtain a true age measure for reasonably large blocks of trees since there are often multiple plantings of trees within the block. The average block of apple orchard on which production data were obtained was 65 acres.

Pruning

The pruning operation requires large labor inputs and is second only to the harvest operation in labor requirements per acre. Hand equipment is still used for a majority of the pruning. This equipment consists of hand saws, shears, loppers (shears on extended handle), and more recently, small gasoline power chain saws. This equipment is used to make the major limb cuts necessary for shaping the tree or removal of dead wood as well as the pruning of small branches of the bearing surface.

Power pruners which use either hydraulic or pnuematic pressure to operate cutting shears or radial saws have been adopted by farmers in recent years. They increase the productivity of the worker by increasing the number of cuts per minute as well as reducing the strenuous nature of work. The simplest of these devices is the pole pruner which has shears that are operated by the hydraulic pressure from the tractor's hydraulic system. With these the worker prunes the portions of the tree that can be reached from the ground and reaches the remainder of the tree by positioning of ladders.

A more elaborate pruning system is one which includes a hydraulic platform or "wishbasket" which can be raised, lowered and positioned from side to side. This enables the worker to reach all portions of the tree by maneuvering the platform. The platform and movable boom are mounted on a trailer which is pulled behind the tractor. The hydraulic system of the tractor provides the power for the boom and hydraulic pruners. A self-propelled hydraulic boom and pruner is available which can be operated by one person. Very few of these units were in operation in Michigan in 1966-1967.

The tree "hedger" type of pruner has been tried with limited success on apple trees. This consists of a cutter bar which shapes the outside dimensions of the tree as you would a hedge. Older trees have such large limbs that they cannot be successfully pruned by this method. It has been more successfully adapted to the newer plantings of semi-dwarf trees which do not reach the size of the older regular stock trees. Even with "hedging" a certain amount of hand pruning is required, however.

The average labor and equipment use observed in the pruning operation is presented in Table 2.1. The farmers reported pruning an average of 68 percent of the total number of trees in their 65 acres of apple orchard. For estimating the average labor and equipment requirements per acre of orchard owned, the upper row of figures in Table 2.1 is appropriate; while the lower row of figures is more appropriate for estimating the productivity of labor and equipment in the pruning operation on actual acres pruned.

Table 2.1 Average Labor and Equipment Use Per Acre in Apple Orchard Pruning (77 farms)

	Tractor Use	Power Pruner	Hand Pruning Equipment	Rake Trailer or Fork	Family Labor	Hired Labor
	(hours)	(hours)	(hours)	(hours)	(hours)	(dollars)
Ave. inputs on total acreage	3.18	2.60	5.75	0.69	5.44	17.83
Ave. inputs on trees actually pruned (68% of total trees)	4.66	3.81	8.44	1.01	7.97	26.12

All of the farmers pruned at least part of their apple acreage in 1966. All 77 farmers used hand pruning equipment to some extent. Thirty-eight used power pruners to supplement their hand equipment. Only two farmers used the "wishbasket" or hydraulic platform for pruning.

The hand pruning equipment was used twice as much as power pruning equipment. Tractor hours were used for the power pruner and with a rake, trailer, fork, or brush cutter for brush removal.

On the basis of analysis performed by Hill, $1.40 per hour appears to be an appropriate wage for hired labor in the pruning operation.[1] Dividing the $17.83 spent on hired labor by $1.40 gives approximately 12.73 hours. When combined with the 5.44 hours of family labor we have an estimate of 18.17 hours of labor per acre.

Tillage

The primary objective of the tillage operation is the control of weeds and grass which compete with the tree for water and plant nutrients and interfere with harvest operations. Tillage practices that range from hand hoeing to the use of herbicides are used to control the growth of grass and weeds. The method of disking the surface of the orchard to control the growth of weeds and grass is effective, but it requires a large number of tractor hours.

Mowing the orchard to control grass and weeds is also effective but requires a large number of tractor hours also. More recently, mowing has been used in conjunction with weed spraying with very good results. One advantage of spraying and mowing is the undisturbed soil surface which provides better traction for equipment being used in the orchard during and

[1] Hill, Resource Use and Returns on Michigan Fruit Farms, p. 60.

immediately after periods of heavy rainfall.

Labor and equipment use in the tillage operation is presented in Table 2.2. Four of the 77 farms used the disk and drag technique exclusively to control weeds and grass. Twenty-one used the disk and drag to some extent. Sixty-two used a mower with 22 using mowing exclusively as the control for weeds and grass. Forty-three used the sprayer with four using the sprayer exclusively as their means of weed and grass control.

The labor use for tillage was not much greater than the amount necessary to operate the tractor and equipment. Evidently there was very little hand tillage on these farms.

Table 2.2 Average Labor and Equipment Use Per Acre in Apple Orchard Tillage (77 farms)

Tractor Use	Disk or Drag	Mower	Weed Sprayer	Family	Hired
(hours)	(hours)	(hours)	(hours)	(hours)	(dollars)
1.74	0.37	1.18	0.20	0.81	1.69

Spraying

The primary purpose of spraying is insect and disease control. In some instances a chemical apple thinner may be applied to reduce the number of apples and increase fruit size. Normally the spray program involves approximately 12 applications of insecticides over an extended period of time.

The most common method for spraying fruit trees involves the use of a tractor and air blast or speed sprayer. The speed sprayer is a high capacity trailer sprayer which may have an auxillary motor or may be driven by the power take-off system of the tractor.

Since the rate of application is very fast with a speed sprayer, a large tank (approximately 500 gallons) was required to avoid excessive stopping to refill with water and spray materials. A 2x concentration of sprays was often used. The use of 4x concentrations allowed spraying to be completed at a faster rate with fewer stops for refilling.

The labor and equipment inputs used in apple spraying are presented in Table 2.3 The tractor and sprayer hours are most appropriately viewed as net time in the field. Time spent in preparation for spraying and mowing is not included in the tractor and sprayer hours. All of the farmers used a speed sprayer of some type for applying their spray materials. The average present value of the tractor and sprayer combination used was $3,775.

Table 2.3 Average Labor and Equipment Use Per Acre in Apple Orchard Spraying (77 farms)

Tractor Use	Sprayer Use	Family Labor	Hired Labor
(hours)	(hours)	(hours)	(dollars)
3.86	3.79	2.26	3.01

Using an average wage of $1.40 for hired labor indicates that 2.15 hours of hired labor were used per acre in the spraying operation. The total labor input was equally divided between family labor and hired labor with a total of 4.31 hours per acre.

Harvesting

The largest use of labor in apple production occurs in the harvesting operation. Of the average $143.63 per acre which was spent on hired labor in the production of apples, $117.74 was spent in the harvest operation.

Fruit Removal

The basic method of fruit removal used on the seventy-seven farms was the traditional method of removing the fruit by hand. In 1966, only one of the farms had used a mechanical harvester to remove apples from the tree by shaking.

Several experimental apple harvesters which use the shaker and catching frame technique for harvesting apples have been tested in recent years. They have failed to gain widespread acceptance, however, One problem has been the reluctance of processors to accept mechanically harvested apples because of higher bruise counts in many cases.

Fruit Handling

The traditional method of hand picking is to place the apples in bushel boxes (approximately 48 pounds of apples) upon removal from the tree. These boxes are then loaded by hand onto a truck or trailer for transporting to storage or the point of sale.

The handling of harvested apples was mechanized to a small degree when these bushel boxes were stacked upon a wooden pallet when filled and removed from the field by loading with a forklift onto a trailer or truck.

More recently, most growers have been using the bulk box to handle apples. The pickers fill the bulk box in the field as they remove the fruit from the tree. The bulk box will hold an average of eighteen bushels of apples. The bottom of the box has a pallet construction which allows the box to be lifted directly onto a truck or trailer with a forklift. The bulk box is also used with the experimental apple harvesters. The fruit is moved directly into the box by a conveyor system. When filled, the box is transported by a forklift.

Forklifts were used on sixty-six of the seventy-seven farms for handling apples. It is not clear in all instances whether the farmer used bulk boxes exclusively or used pallets and bushel boxes. It appears that apple farmers have been adopting the only available labor-saving devices for harvesting. The tractor and forklift or self-propelled fork was the most heavily used piece of equipment with 5.11 hours per acre (Table 2.4).

The hand harvest equipment (ladders and picking bags) was used an average of 3.10 hours per acre (Table 2.4). Translated in terms of the average of 64.5 acres of trees this gives 200 hours of harvest time or 20 ten-hour days of harvesting.

Type of Labor

The harvest labor was primarily hired laborers who were paid on a piecework basis for picking. The piecework rate averaged approximately

$.25 per bushel. Hired labor for the harvest operation cost an average of $118 per acre. An average of 5.15 hours per acre of family labor was used in conjunction with the hired labor.

Table 2.4 Average Labor and Equipment Use in Apple Orchard Harvesting (77 farms)

Tractor Use	Tractor & Fork or Self-propelled fork	Hand Harvest Equipment Used in Field	Truck	Trailer	Misc.	Family Labor	Hired Labor
(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(dollars)
2.08	5.11	3.11	1.77	2.42	0.07	5.15	117.74

Miscellaneous Operations

Miscellaneous operations cover all those operations performed which were not clearly in one of the other four categories. As can be seen by an examination of Table 2.5, they account for a very small proportion of the total labor and equipment use in apple production.

Table 2.5 Average Labor and Equipment Use in Apple Orchards for Miscellaneous Operations (77 farms)

Tractor Use	Miscellaneous Equipment	Family Labor	Hired Labor
(hours)	(hours)	(hours)	(dollars)
0.59	0.79	0.64	3.36

Comparison of Levels of Inputs Used in the Operations

The quantities of three classes of inputs used per acre in the five operations are presented in Table 2.6. The harvesting operation requires the largest hired labor expenditure of $117.74 per acre. This is over four times as large as the combined labor expenditures of all other operations. The importance of labor reduction in harvesting is quite apparent. Machinery costs were also highest in harvesting, but only slightly higher than for spraying.

Table 2.6 Quantities of Labor and Machinery Inputs Used Per Acre in Major Operations Performed in Apple Production on 77 Farms in 1966.[a]

Operation	Input Category		
	Machinery Costs[b]	Hired Labor Expenditures	Family Labor
	(dollars)	(dollars)	(hours)
Pruning	10.76	17.83	5.44
Tillage	6.20	1.69	0.80
Spraying	28.88	3.01	2.26
Harvest	30.88	117.74	5.15
Miscellaneous	1.98	3.36	0.64

[a]Average production of 372 bushels per acre on average acreage of 64.5 acres.

[b]Machinery cost estimate obtained by valuing one hour's use of $1,000 value of machinery at $2.00.

Practices Used in Tart Cherry Production

The practices used in tart cherry production are quite similar to those used in apple production. Practices which differ will be discussed more fully than those which were described previously for apples.

Tart cherry trees are generally smaller in size than apple trees found in Michigan orchards. There were an average of ninety-three cherry trees per acre on the sample farms. The most common spacing was twenty feet by twenty feet (108 trees per acre). Some of the newer plantings have considerably more than 100 trees per acre. Some farmers are developing closer spacings within rows for a hedgerow effect. The average age of cherry orchards in the sample of 68 farms was nineteen years. The average block of cherry orchard on which production data were obtained was 35 acres.

Pruning

The pruning operation in cherries requires a large amount of labor as can be seen by examining Table 2.7. The farmers reported pruning an average of fifty-four percent of the total number of cherry trees in their average total acreage of 35 acres. This is a very common practice for cherry growers to prune each tree every two years on the average rather than trying to prune all of the trees every year. Therefore, for estimating the average labor and equipment requirements per acre of orchard owned the upper row of figures in Table 2.7 is appropriate while the lower row of figures is more appropriate for estimating the productivity of labor and equipment per acre actually pruned.

The use of the tractor as a source of power for the power pruner and in combination with a rake, trailer, or brush chopper for the removal of brush accounts for the major part of the total tractor use. The power pruner was used only one-fourth as many hours as hand equipment indicating a heavy use of hand equipment in the pruning operation. Five of the farmers indicated that they did not prune in 1966. Thirteen used power pruners for pruning. None of the farmers indicated they had used the pruning platform or wishbasket although two owned pruning platforms.

Table 2.7 Average Labor and Equipment Use Per Acre in Cherry Orchard Pruning (68 farms)

	Tractor Use	Power Pruner	Hand Pruning Equip- ment	Rake, Trailer or Fork	Family Labor	Hired Labor
	(hours)	(hours)	(hours)	(hours)	(hours	(dollars)
Ave. inputs on total acreage	2.51	1.24	5.02	0.79	5.59	12.32
Ave. inputs on trees actually pruned (54% of total trees)	4.61	2.29	9.23	1.45	10.28	22.64

On the basis of analysis performed by Hill, $1.40 per hour appears to be an appropriate wage for hired labor in the pruning operation. Using the $1.40 wage the $22.64 spent on hired labor would be 16.16 hours of hired labor. Hired labor plus family labor gives a total labor input of 26.44 hours per acre of orchard pruned, or 14.38 hours per acre of orchard owned.

Tillage

The primary equipment used in the tillage operation was the disk and/or drag or some other tillage implement such as the culticutter. The farmers spent approximately three hours per acre on the disking and dragging operations (Table 2.8). Forty-eight used disking and dragging exclusively as their method of weed control. Fourteen used mowing as a weed control with seven using mowing exclusively as their method of weed control. Ten used chemical weed sprays in combination with another weed control technique. It appears that cherry producers have been rather slow to substitute chemical weed control for traditional methods.

Table 2.8 Average Labor and Equipment Use Per Acre in Cherry Orchard Tillage (68 farms)

Tractor Use	Disk or Drag	Mower	Weed Sprayer	Rental or Custom	Family Labor	Hired Labor
(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(dollars)
3.19	2.98	0.20	0.05	0.059	1.77	2.19

The continued use of the disk and drag technique of weed control may not be unrealistic from the viewpoint of the farmer who owns equipment for the job and has regular hired (nonseasonal) labor available on the farm to perform the job. With the adoption of mechanical cherry harvesters there may be other reasons for changing to chemical weed control and mowing as a replacement for the disk and drag method. Mechanical harvesting requires a solid and reasonably even terrain around the trees to facilitate the positioning of the catching frames and the movement of water tanks to transport cherries. A good grassed surface will provide more support for equipment during very wet weather than a freshly tilled soil. Disking and dragging also tend to build up mounds of earth at the base of the tree if done improperly. This creates problems with positioning of catching frames beneath trees that have a low scaffold structure as found in many of the older orchards.

The labor for the tillage operation appears to be composed almost equally of family labor and hired labor. Most of the tillage operations are performed during the summer months when the family labor supply is bolstered by school children who are capable of performing most of the tillage operations satisfactorily.

Spraying

The air blast type sprayer was used almost exclusively for applying insecticides to cherries. The use of 4x concentration sprays is also most prevalent among cherry growers. The average present value of the tractor and sprayer combination used was $4,280.

Family labor accounts for more than one-half of the total labor input in the spraying operations (Table 2.9). This is to be expected since the spray operations are of such importance that close supervision of the operation is necessary, and the input is low enough on many farms that the operator and his family can provide it.

Table 2.9 Average Labor and Equipment Use Per Acre in Cherry Orchard Spraying (68 farms)

Tractor Use	Sprayer Use	Family Labor	Hired Labor
(hours)	(hours)	(hours)	(dollars)
1.78	1.78	1.25	0.99

Harvesting

The most intensive and largest use of labor occurs in the harvest operation. Of the $150.34 per acre which was spent on hired labor in the production of cherries, $124 was spent in the harvest operation. The harvest season is usually spread over a 2-3 week period in late July requiring large amounts of labor for short periods of time.

Fruit Removal

There were two basic methods of fruit removal used on the farms. The traditional practice of removing fruit by hand was the most common method. There were, however, 17 of the farms that used mechanical cherry shakers to remove the fruit from at least part of their cherry acreage. The latter method involves the substitution of machinery capital for labor in the harvesting process which has historically been a very labor intensive operation.

Fruit Handling

With hand picking the cherries are normally placed in lugs (wooden boxes holding approximately 27 pounds of cherries) which are transported to the processing plant. The traditional method of handling the lugs is to load them by hand on the trailer or truck for transporting to the processor. Some labor saving occurs when the lugs are loaded on pallets in the field as they are filled and subsequently placed on a truck or trailer by a forklift. Mechanically harvested cherries are most commonly placed directly into bulk tanks which are filled with cold water. These bulk tanks have to be handled with a forklift due to their size and weight.

Forklifts were used to handle at least part of the cherries on the 17 farms which used mechanical harvesters. Of the 51 farms that used hand picking exclusively only 8 used forklifts. The remaining 43 farms used the hand loading system. It appears that many farmers have not been sufficiently motivated to adopt forklift and pallet handling as a labor saving technique. The continued use of hand loading accounts for the relatively high use of the tractor, truck, and trailer complement of equipment relative to the forklift in the harvest operation.

The hand harvest equipment such as picking buckets and ladders was used in the field for an average of 4.35 hours per acre (Table 2.10). Translated in terms of the average of 35 acres of trees this gives approximately 150 hours of harvest time or 15 ten-hour days of harvesting for a large crew of 25 to 30 workers.

Table 2.10 Average Labor and Equipment Use in Cherry Orchard Harvesting (68 farms)

Tractor Use	Tractor & Fork or Self-propelled Fork	Hours Hand Harvest Equipment Used	Harvester & Tanks	Truck	Trailer	Misc.	Family Labor	Hired Labor
(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(dollars)
3.85	1.49	4.35	0.61	1.59	3.88	0.99	4.49	124.0

Type of Labor

The harvest labor was primarily hired laborers who were paid on a piecework basis for picking with payment on a hourly wage basis for other harvest operations. Hired labor for the harvest operation cost an average of $124 per acre. An average of 4.5 hours of family labor was used in conjunction with the hired labor.

Miscellaneous Operations

Miscellaneous operations cover all those operations performed which were not clearly in one of the other four categories. As can be seen by an examination of Table 2.11 they account for a very small proportion of the total labor and equipment use in apple production.

Comparison of Levels of Inputs Used in the Operations

The quantities of three classes of inputs used per acre in five operations for cherry production are presented in Table 2.12. The

Table 2.11 Average Labor and Equipment Use in Cherry Orchards for Miscellaneous Operations (68 farms)

Tractor Use	Miscellaneous Equipment	Family Labor	Hired Labor
(hours)	(hours)	(hours)	(dollars)
0.49	0.40	0.35	0.52

Table 2.12 Quantities of Labor and Machinery Inputs Used Per Acre in Major Operations Performed in Cherry Production on 68 Farms in 1966.[a]

	Input Category		
Operation	Machinery Costs[b]	Hired Labor Expenditures	Family Labor
	(dollars)	(dollars)	(hours)
Pruning	7.64	7.04	4.65
Tillage	13.32	2.19	1.77
Spraying	15.24	0.99	1.25
Harvest	50.30	124.0	4.46
Miscellaneous	1.34	0.52	0.35

[a]Average production of 1.90 tons per acre on average acreage of 35.18 acres.

[b]Machinery cost estimate obtained by valuing one hour's use of $1,000 value of machinery at $2.00.

harvesting operation requires the largest hired labor expenditures of $124 per acre. This is eleven times as large as the combined labor expenditures of all other operations. The importance of labor reduction in harvesting is quite apparent. Machinery costs for cherry harvesting were also the highest of all operations.

Summary

It appears that apple producers are adopting the tested labor saving techniques of production at a moderately fast rate. Approximately one-half were using power pruners although only two used the pruning platform. Over one-half have adopted weed spraying. All of the farmers used a speed sprayer for applying spray materials. The largest source of labor use, harvesting, has not been mechanized to any large extent for apples. Only the fruit handling stage has been mechanized. This was the only tested labor saving technique that was available at the time of the interviews.

In contrast, it appears that tart cherry producers have been less aggressive in the adoption of certain advanced production techniques. Only one-fifth of them were using power pruners in the pruning operation. Seventy percent were using weed sprays while none were using them exclusively as their method of weed control. All of them appeared to be using modern insecticide application techniques.

Seventeen of 68 farms were using an advanced technique (mechanical cherry harvester) in their harvest operation. Only 8 of the 51 using hand harvesting used forklifts to handle lugs of cherries. This rapid rate of adoption of mechanical harvesters by some and failure to adopt forklifts as an intermediate level of mechanization by a majority provides an interesting contrast. It would appear that there is a certain threshold where the labor savings have to be large, as in the case of mechanical harvesting, before the farmer adopts the new practice. The decision to change may not be entirely based on a comparative cost of production nationale due to a reluctance to depart from a tried and proven technique for a small savings in production cost.

CHAPTER III

APPLE PRODUCTION FUNCTIONS

Source of Data

The data for the enterprise production functions were obtained from the sample of 258 farms mentioned in Chapter I. On each of the 258 farms the farmer was asked to give detailed production data for one or two fruits on his farm.

The data obtained for apples at the individual enterprise level were limited to reasonably homogeneous blocks of bearing apple orchards. In some cases this consisted of the entire apple acreage of the farmer. Apple enterprise data were not obtained in those cases where the farm had experienced unusual weather conditions which had severely reduced production for that year.

The information obtained consisted of inputs of labor and machinery used in operations incurred in the production of apples in 1966. These were enumerated on a chronological basis for the operations performed during the year. The variables for the production function analysis were developed from the information obtained in the manner described above. Seventy-seven usuable schedules were obtained for apple production at the enterprise level.

Selection of Functional Form

The selection of a functional form to agree with the underlying economic concepts of production theory is never an easy choice. Given the nature of the raw data it was believed that a relatively simple production function model that had acceptable economic properties was the best choice.

A function which was linear in the original data and the Cobb-Douglas function (linear in the logarithms) were considered. The Cobb-Douglas function was chosen for the following reasons: (1) it provided an adequate fit of the data; (2) it is an efficient user of degrees of freedom; (3) it is computationally feasible; (4) it is the least complicated function that allows diminishing returns; and (5) it yields elasticities directly.

As mentioned, the Cobb-Douglas will allow either constant, increasing, or decreasing returns to scale to be exhibited singly by the function. However it will not allow any combination of constant, increasing, or decreasing returns to be exhibited simultaneously by the same function. The β_i coefficients are the production elasticities of the respective factors of production. The Cobb-Douglas function requires constant elasticities of production. The sum of the elasticities ($\Sigma \beta_i$) is an indication of the nature of returns to scale. If $\Sigma \beta_i = 1$, a one percent increase in inputs will result in a one percent increase in output. If $\Sigma \beta_i$ is less than or greater than 1, output will increase by a smaller or greater percentage, respectively, than inputs.[1]

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[1]For elaboration on the historical development and properties of the Cobb-Douglas type production function the interested reader may see

The Cobb-Douglas function was fitted as a single equation model using classical least squares regression analysis. The regression model was of the following form:

$$Y_i = \cdot X_1^{\beta 1} \; X_2^{\beta 2}, \; . \; . \; . \; ,. \; X_n^{\beta n} \mu_i$$

Where Y_i is the dependent variable, α is a constant, X_1, X_2, . . . , X_n are independent variables, and β_1, β_2, . . . , β_n are parameters, i.e., the population regression coefficients, and μ_i is a random error term. The function is estimated by transforming the original data into a linear in logs equation and fitting by least squares.

The assumptions necessary in order to obtain best linear unbiased estimates of Y_i using ordinary least squares are: (1) the μ's are randomly distributed with zero means and uniform variance; (2) the μ's are serially independent; (3) the X's are predetermined; and (4) the X's are measured without error.[2] The assumption of normality is necessary for testing estimates.

Earl C.. Heady and John Dillon, Agricultural Production Functions, (Ames, Iowa: Iowa State University Press, 1961), pp. 16-30, 75-77, 83-86.

[2]Lester V. Manderscheid, "An Introduction to Statistical Hypothesis Testing," (Mimeographed Agricultural Economics No. 867, revised, East Lansing, Michigan, Department of Agricultural Economics, Michigan State University,, 1964), pp. 19-20.

Apple Enterprise Functions

Description of the Variables

Value of Production

The dependent variable was the total value of fruit sold from the orchard in 1966. The total value was obtained by multiplying the production by the blend price of $1.55 per bushel. The blend price was used because of the unreliability of estimates of the proportion of the crop sold at various processing prices. Thus, the variable is essentially an index of physical production converted to dollar terms.

Number of Trees

The number of trees per observation, i.e., per orchard was used as a factor of production. The number of trees was considered a better measure of the input than the acres of orchard because it measures the variation in spacing among orchards better.

Hours Use of $1,000 Value of Equipment

The machinery input was developed from the information obtained on the schedules in the following manner. The hours of equipment use was recorded for each operation performed in the production of apples. In order to standardize the machinery input, the value of the equipment used was divided by $1,000 and multiplied by the hours of use to obtain the hours use of $1,000 value of equipment.[3]

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[3]Additional explanation of machinery valuation is included in Appendix A.

Custom Operations

This is the measure of the inputs purchased by the farmer for those operations such as pruning, spraying, and harvesting that were performed on a custom operation basis or for which custom equipment was rented. The variable is expressed in terms of dollar expenditures.

Family Labor

The hours of direct family labor input as recorded by operations performed is used as an input variable. No discrimination was made between types of labor, i.e., operator, wife, or other family.

Hired Labor

The dollar cost of hired labor was recorded for each operation and aggregated for the enterprise. A sizable quantity of hired labor was used in the harvest operation and received a piece-rate wage. This made it impossible to use hours of hired labor as an input.

Other Considerations

No building inputs have been used in the apple function. It is assumed that apple storage operations belong to a different production process than apple growing. Buildings contribute to processes that change the form of the field product through packing or storage in order to obtain higher seasonal prices.

The Function For Total Sales (Model I-A)

The Regression Fitting

The apple enterprise production function was fitted to 77 observations.

The regression was of the form:

$$\hat{Y}_1 = a\, X_1^{\,b_1}\, X_2^{\,b_2}\, X_3^{\,b_3}\, X_4^{\,b_4}\, X_5^{\,b_5}$$

Where

$\hat{Y}_1$ = the estimate of sales per orchard in 1966;

a = constant;

b_i = estimate of the regression coefficient associated with the i^{th} variable;

X_1 = number of trees per orchard in 1966;

X_2 = hours use of $1,000 value of equipment in the orchard in 1966;

X_3 = dollars spent on custom operations in the orchard in 1966;

X_4 = hours of family labor used in production in 1966; and

X_5 = dollars spent for hired labor in production in 1966.

The computed regression equation was:[4]

$$\hat{Y}_1 = 17.398\, X_{1\,(0.07836)}^{\,0.51270***}\; X_{2\,(0.08115)}^{\,0.22354***}\; X_{3\,(0.03688)}^{\,-0.01146}\; X_{4\,(0.02156)}^{\,0.02601}\; X_{5\,(0.05019)}^{\,0.18809***}$$

$\hat{Y}_1 = 17.398\, X_{1\,(0.07836)}\; X_{2\,(0.08115)}\; X_{3\,(0.03688)}$

[4]Numbers in parenthesis indicate the respective standard errors of the estimates of β_i. Tabled "t" values are 1.296, 1.671, and 2.390 at the .10, .05, and .01 levels of significance, respectively for 70 degrees of freedom. One asterick (*) indicates significance at the .10 level. Two astericks (**) indicate significance at the .05 level. Three astericks (***) indicate significance at the .01 or higher level.

The coefficient of multiple determination was .87, indicating that 87 percent of the variation in sales was associated with changes in the specified input quantities. The sum of the elasticities (Σb_i) was 0.94 which is not significantly different from 1. The highest simple correlation among the independent variables was 0.79 for number of trees and hired labor.[5] Multicollinearity was not considered to be a significant factor in view of the observed size of the variances of fitted independent variables.

The elasticities for trees, machinery use, and hired labor were significantly different from zero at the 1 percent level of probability. However, the elasticities for custom operations and family labor were not significantly different from zero at levels of probability as low as 10 percent. On the basis of these significance levels one could say that the variation in sales per orchard was primarily attributable to variation in number of trees, machinery use, and hired labor; with custom operations and family labor not having a statistically significant basis as explanatory variables although they are included in the economic model.

Marginal Value Products

The marginal value products of the inputs are shown in Table 3.1. The marginal value product of an input is the value added to total product by increasing the input one more unit beyond the specified level.[6]

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[5]Simple correlations for all of the regression equations are contained in Appendix B.

[6]Marginal value product, (MVP), is defined as $MVP = b_i \frac{\hat{Y}}{X_i}$ for the Cobb-Douglas function. Marginal value productivities of

Table 3.1 Marginal Productivities at Mean Input Levels for Apple Enterprise Function (Model I-A)

Input Category	Geometric Mean	Marginal Value Product at Geometric Mean
Trees	1,842 trees	$7.11 per tree
Machinery	1,790 hours	$3.19 per hour use
Custom Operations[a]	$1.34	0
Family Labor	406 hours	$1.63 per hour
Hired Labor	$5,234	$0.91 per dollar

[a]See footnote 6 for explanation.

The marginal value product of $7.11 per tree can be viewed as the annual return attributable to adding an additional bearing apple tree. With the observed average of 40 trees per acre this would amount to an MVP of $284.40 per acre.

The marginal value product of an hour's use of $1,000 value of machinery was $3.14. If we assume a cost of $2.00 per hour use of $1,000 value of machinery then the MVP of an additional hour of machinery use is greater than the cost.[7]

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inputs with negative elasticities would necessarily be negative. Use of a resource to the point where the MVP is negative is not rational in an economic sense. Therefore, it will be assumed that resources with negative elasticities have MVP's of zero for purposes of analysis.

[7]For elaboration on the cost of machinery use, see Appendix C.

The marginal value product of an hour of family labor was \$1.63. The elasticity of family labor was not significantly different from zero at the 10 percent level, so there is little basis for confidence in the estimate of the MVP.

The marginal value product of hired labor indicates that the addition of \$1.00 of hired labor results in only \$.91 change in total product. This indicates that too much hired labor was being used.

Production Isoquants

According to classical theory of the firm the least cost combination of resources to use in production of a given amount of product can be expressed in the two input case as:

$$\frac{MPP_1}{P_1} = \frac{MPP_2}{P_2}$$

Where MPP_1 and MPP_2 are the marginal physical products of inputs X_1 and X_2 respectively, and P_1 and P_2 are the prices of inputs X_1 and X_2. It is assumed that the prices paid per unit of input by these farmers are independent of the quantities used. If they were in fact influenced by the quantities used we would have to substitute MFC_1 for P_1, where MFC (marginal factor cost) varied with output. These conditions can be extended to n inputs as follows:

$$\frac{MPP_1}{P_1} = \frac{MPP_2}{P_2} = , \ldots , = \frac{MPP_n}{P_n}$$

The least cost combination of two variable inputs can be illustrated conveniently by the use of production isoquants as illustrated in Figure 3.1.

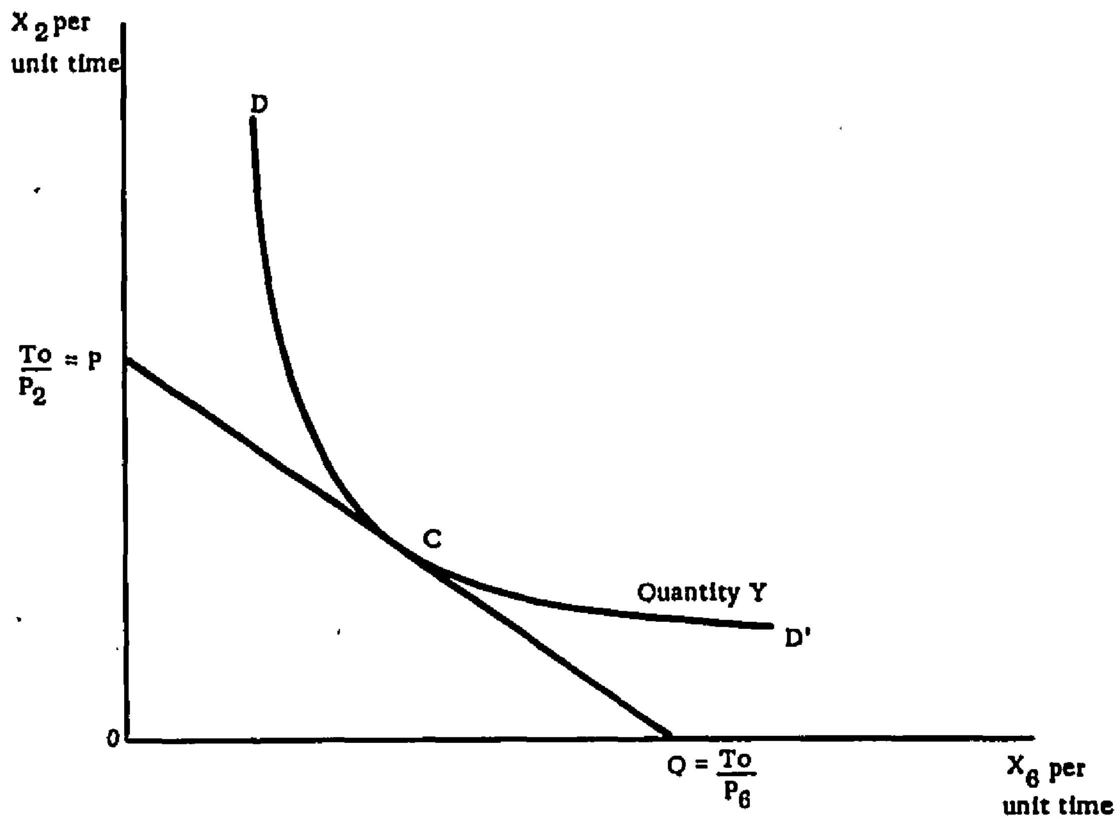

Figure 3.1 Representative Isocost and Isoquant

An isoquant shows the different combinations of two resources which can be used to produce a given amount of product.

The isoquant curve D D' in Figure 3.1 shows the different combinations of the two resources X_2 and X_6 which can be used to produce the output Y represented by D D'. At any point on the isoquant the marginal rate of technical substitution of X_2 for X_6 is equal to $\frac{MPP_{x2}}{MPP_{x6}}$. The isocost line P Q shows the various combinations of X_2 and X_6 which could be purchased with a given money expenditure. The slope of the isocost equals $\frac{P_{x_2}}{P_{x_6}}$. The point of tangency, (C), of the isocost line to the isoquant represents the least cost combination of resources X_2 and X_6 in producing quantity Y. At the point of tangency, $\frac{MPP_{x_2}}{MPP_{x_6}} = \frac{P_{x_2}}{P_{x_6}}$ which can be converted to $\frac{MPP_{x_2}}{P_{x_2}} = \frac{MPP_{x_6}}{P_{x_6}}$ by rearranging the terms of the equation. For discussion purposes we will equate the marginal rate of technical substitution, $\frac{MPP_{x_2}}{MPP_{x_6}}$, to the price ratio of the resources, $\frac{P_{x_2}}{P_{x_6}}$.[8]

The apple production function was used as the basis for estimating the data in Table 3.2. Included in the data are: (a) the combination of hours of use of $1,000 machine value and dollar cost of hired labor that will produce the mean apple production of $25,569, and (b) marginal rates of substitution between these factors.

The isoquants of the Cobb-Douglas function have assymptotic properties which probably lead to overestimation of the substitution rates for factor combinations extending away from the mean combination of inputs.[9] The range of combinations has been essentially restricted to those that represent combinations of a minimum of one-half and a maximum of twice the mean input of the resource under consideration.

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[8]For a discussion of the relationship of isoquants and isocosts to least cost combinations of resources see Richard H. Leftwich, The Price System and Resource Allocation, 3rd edition, (New York: Holt Rinehart and Winston, 1966). pp 117-125.

[9]Heady, Agricultural Production Functions, p. 84.

Table 3.2 Mean Isoquant and Marginal Rates of Substitution for Machinery and Labor in Apple Production (Model I-A)

Isoquant (Combinations of hours of machinery use and hired labor to produce average production of $25,569)		Marginal Rate of Substitution of Machinery Use for Labor[a]
Input of Machine Use [hours use of $1,000 value of equipment, (X_2)] Geometric mean, $\bar{X}_2$ = 1,790	Quantity of labor in dollar value, (X_5), Geometric mean, $\bar{X}_5$ = 5,233	
(hours)	(dollars)	
500	23,819	56.61
700	15,968	27.11
900	11,845	15.64
1,100	9,332	10.08
1,300	7,651	6.99
1,500	6,455	5.11
1,700	5,562	3.88
1,900	4,874	3.04
2,100	4,327	2.45
2,300	3,884	2.01
2,500	3,517	1.67
2,700	3,210	1.41
2,900	2,949	1.21
3,100	2,724	1.04
3,300	2,529	0.91
3,500	2,358	0.80

[a]Negative sign omitted.

Column 3 of Table 3.2 shows the marginal rate at which machinery use substitutes for hired labor. These rates of substitution are based on derivatives at the exact combinations indicated, and will not agree with averages between combinations. The rate of substitution of machinery for labor declines as the quantity of machine use increases. A relatively small machine input is apparently very profitable with relatively less value as a labor replacement after the level of hours provided by a basic complement of machinery has been reached.

At the combination of 500 hours use of $1,000 value of equipment (referred to as "machinery use") and $23,819 of hired labor, a one hour increase in machinery use will replace $56.61 of hired labor. At the combination of 3,500 hours of machinery use and $2,358 of hired labor, however, a one hour increase in machinery use would replace only $.80 of hired labor.

If we assume a cost of $2.00 per hour of use of $1,000 value of equipment commonly used on fruit farms and a cost of $1.00 for $1.00 of hired labor, we obtain a price ratio of 2. Equating this price ratio with the marginal rate of substitution of machinery for labor use would give the least cost combination of resources to use to produce the mean output of $24,569. The value of 2.01 in Column 3 of Table 3.2 is approximately equal to 2, indicating a combination of 2,300 hours of machinery use and $3,884 of hired labor. This is slightly more machinery use and slightly less labor use than the observed means of 1,790 hours of machinery use and $5,233 of hired labor.

Apple Enterprise Function for Sales per 100 Trees (Model III-A)

The apple production function with total sales as the dependent variable which was reported above included the number of trees as a variable. In contrast a function was fitted to the data expressed in terms of inputs per 100 trees.[10] The variables in the resulting model are all in terms of a flow of services per 100 trees. This is the equivalent of forcing constant returns to scale upon the production function. Since the sum of the coefficients in the total sales equation (Model I-A) indicated no significant difference from constant returns to scale, the coefficients for the variables in Model III-A were essentially the same. The results of the fitting did not contribute enough to the analysis to merit more detailed discussion and are included in Appendix B.

Apple Harvesting Operation Functions

As mentioned earlier, the harvest operation requires the largest use of labor of any single operation in the entire production process. It was thought that production function analysis would give insights into the current substitution relationships between machinery and hired labor in apple harvesting. Two production functions were fitted to the data for the apple harvesting operation.

The Function for Total Sales (Model V-A)

Total apple sales were chosen as the dependent variable for the regression fitting because the total apple harvest is the direct measure of the productivity of the harvest operation.

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[10]The factor of 100 trees was selected as an arbitrary number that provided: (1) a convenient divisor, and (2) corresponded to the approximate average number of trees per acre of cherries and per 2.5 acres of apples.

The Regression Fitting

The apple harvesting function was fitted to the same 77 observations which the apple enterprise functions were fitted.

The regression was of the form:

$$\hat{Y}_5 = a \cdot X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4}$$

Where:

$\hat{Y}_5$ = the estimate of sales per orchard in 1966;

a = constant;

b_i = estimate of the regression coefficient associated with the i^{th} variable;

X_1 = number of trees per orchard in 1966;

X_2 = hours use of \$1,000 value of equipment in the harvesting operation in 1966;

X_3 = hours of family labor used in harvesting in 1966;

X_4 = dollars spent for hired labor in harvesting in 1966.

The computed regression was:

$$\hat{Y}_5 = 26.638\, X_1 {}^{0.6423^{***}}_{(0.0623)} \quad X_2 {}^{0.1343^{***}}_{(0.0533)} \quad X_3 {}^{-0.0046}_{(0.0183)} \quad X_4 {}^{0.1443^{***}}_{(0.0404)}$$

The coefficient of multiple determination, R^2, was 0.86.

The adjusted coefficient of multiple determination, $\bar{R}^2$, was 0.85.

The sum of the elasticities was 0.924 which was not significantly different from 1 at levels as high as 0.5 percent. The simple correlations were not large enough for concern over multicollinearity.

The elasticities for trees, machinery use, and hired labor were significantly different from zero at the 1 percent level of probability.

The elasticity of family labor was not significantly different from zero at a probability level as low as 10 percent. It appears that the variation in sales due to the harvest operation was primarily attributable to variation in trees, machinery use, and hired labor.

Marginal Value Products

The marginal value products of the inputs are shown in Table 3.3. The MVP of $8.91 for an additional bearing apple tree can be viewed as the marginal annual return attributable to adding an additional bearing apple tree on which the harvest operation would be performed. This appears to be a reasonably good return to additional trees.

Table 3.3 Marginal Productivities at Mean Input Levels for Apple Harvesting Function (Model V-A)

Input Category	Geometric Mean	Marginal Value Product at Geometric Mean
Trees	1,842 trees	$8.91 per tree
Machinery	628.15 hours	$5.47 per hour
Family labor[a]	90.7 hours	0
Hired labor	$3,882.91	$0.95 per dollar

[a]Negative b value so MVP assumed to be zero.

The marginal value product was $5.47 for an additional hour's use of $1,000 value of machinery. The MVP is considerably larger than the cost of $2.00 per hour use of $1,000 value of machinery that was assumed earlier. It appears to be profitable to expand the use of machinery in the harvest operation.

The marginal value product of family labor is assumed to be zero since the elasticity coefficient for family was not significantly different from 0 although it had a negative sign. The marginal value product of $.95 for hired labor indicates that an excess of hired labor is being used. The addition of hired labor would result in a $.05 dollar loss per dollar of additional labor hired.

Production Isoquant

The apple harvesting operation function was used as the basis for estimating the isoquant data of Table 3.4. Included in the data are: (a) the combination of hours of use of $1,000 value of machinery and dollar cost of hired labor used in the harvest operation to produce the mean apple production of $25,570 and (b) marginal rates of substitution between these factors.

Assuming a cost of $2.00 per hour of use of $1,000 value of equipment commonly used in harvest operations and a cost of $1.00 for $1.00 of hired labor, we obtain a price ratio of 2. Equating this price ratio with the marginal rate of substitution of machinery for labor use, we obtain the least cost combination of machinery use and hired labor in the harvest operation to produce the mean output of $25,570. The value of 2.02 in Column 3 of Table 3.4 indicates a combination of 1,080 hours of machinery use and $2,344 of hired labor. This represents an increase of 452 hours of machinery use above the observed mean level of 628 hours. Likewise, it represents a decrease of $1,539 of expenditures for hired labor.

Table 3.4 Mean Isoquant and Marginal Rates of Substitution for Machinery and Labor in Apple Harvesting (Model V-A)

Isoquant (Combination of hours of machinery use and hired labor to produce average production of $25,569.86)		Marginal Rate of Substitution of Machinery Use for Labor
Input of machine use [hours use of $1,000 value of equipment, (X_2)] Geometric mean, $\overline{X}_2$ = 628	Quantity of labor in dollar value, (X_4) Geometric mean, $\overline{X}_4$ = $3,882.91	
(hours)	(dollars)	
200	11,269	52.45
240	9,510	36.89
280	8,238	27.39
320	7,275	21.17
360	6,520	16.86
400	5,910	13.78
440	5,409	11.44
480	4,988	9.67
520	4,630	8.29
560	4,321	7.18
600	4,052	6.28
640	3,816	5.55
680	3,607	4.94
720	3,420	4.42
760	3,252	3.98
800	3,100	3.61
840	2,962	3.28
880	2,837	3.00
920	2,722	2.75
960	2,616	2.54
1,000	2,519	2.34
1,040	2,428	2.17
1,080	2,344	2.02
1,160	2,194	1.76
1,240	2,062	1.55
1,320	1,945	1.37
1,400	1,841	1.22

If, in fact, the cost of machinery use has been underestimated, the adjustment would be of smaller magnitude than was indicated above. It is doubtful that the cost of machinery use would be as high as $5.55 which would be the cost necessary to equate the price ratios with a marginal rate of substitution which approximates the mean combination of 628 hours of machinery use and $3,883 of hired labor. The MVP's of machinery use and hired labor are consistent with an increase of machinery use (MVP = $5.47 per hour) and a decrease in hired labor (MVP = $.95 per dollar). It appears that the least cost combination of the two resources would require more machinery use and less hired labor even if higher machinery costs were used.

The Function for Sales Per 100 Trees (Model VI-A)

As with the enterprise production function, the inputs for the harvest operation regression were deflated to a per 100 tree basis. Since the sum of the coefficients in the total sales equation (Model V-A) indicated no significant difference from constant returns to scale, the coefficients for the variables in Model VI-A were essentially the same. The results of the fitting did not contribute enough to the analysis to merit more detailed discussion and are included in Appendix B.

Apple Pruning Function (Model VII-A)

The production function for the pruning operation was fitted using the number of trees upon which the operation was performed as the dependent variable. The number of trees upon which the pruning operation is performed is not predetermined in any given year. The number of trees pruned is a function of the equipment and labor available during the winter months for pruning. As reported in Chapter II, apple producers in the sample pruned an average of 68 percent of the total number of trees owned in 1966. It appears to be appropriate to use the number of trees pruned as the dependent variable. Earlier fitting of some exploratory production functions with total sales as the dependent variable had indicated that the relationship between total sales and this operation was such that total sales was not the appropriate measure of output from the operation.

The Regression Fitting

The pruning operation function was fitted to seventy-six observations. The regression was of the form:

$$\hat{Y}_7 = a X_1^{b_1} X_2^{b_2} X_3^{b_3}$$

Where:

$\hat{Y}_7$ = the estimate of the number of trees pruned per orchard in 1966;

a = constant;

b_i = estimate of the regression coefficient associated with the i^{th} variable;

X_1 = hours use of $1,000 value of equipment in the pruning operation;

X_2 = hours of family labor used in pruning in 1966;

X_3 = dollars spent for hired labor in pruning in 1966.

The computed regression was:

$$\hat{Y}_7 = 146.99 \; X_1{}^{0.2657***}_{(0.0764)} \; X_2{}^{0.0097}_{(0.0390)} \; X_3{}^{0.1351***}_{(9.0377)}$$

The coefficient of multiple determination, R^2, was .38.

The adjusted coefficient of multiple determination, $\bar{R}^2$, was .35.

The sum of elasticities was 0.41 which was significantly different from 1 at the one percent level of significance. The simple correlations were not high enough to indicate any problems with multicollinearity.

The elasticities for machinery use and hired labor were significantly different from zero at the one percent level of probability. The coefficient for family labor was not significant at acceptable levels of probability.

Marginal Physical Products

The marginal physical products of the inputs are shown in Table 3.5. In order to compare the MPP of machinery use and hired labor, we can assume a price for machinery and compute the MPP per dollar of machinery use. Assuming a price of $2.00 per hour use of $1,000 value of equipment as a maximum price, we get a value of one tree per dollars worth of machinery use. The MPP of machinery use is larger than that of hired labor.

Table 3.5 Marginal Productivities at Mean Input Levels for Apple Pruning Function (Model VII-A)

Input Category	Geometric Mean	Marginal Physical Product at Geometric Mean
Machinery	162.1 hours	2.01 trees per hour
Family labor[a]	71.5 hours	0.17 tree per hour
Hired labor	$222.65	0.75 tree per dollar

[a]Computed from nonsignificant b value.

Production Isoquant

The apple pruning operation function was used as the basis for estimating the isoquant data of Table 3.6. Included in the data are: (a) the combination of hours of use of $1,000 value of machinery and dollar cost of hired labor used in the pruning operation to prune the mean of 1,229 trees per farm, and (b) marginal rates of substitution between these factors.

Assuming a cost of $2.00 per hour of use of $1,000 value of equipment commonly used in the pruning operation and a cost of $1.00 for $1.00 of hired labor, we obtain a price ratio of 2. Equating this price ratio with the marginal rate of substitution of machinery for labor, we obtain the least cost combination of 180 hours use of $1,000 value of equipment and $181 of hired labor to prune the mean output of 1,229 trees. This is more machinery and less hired labor expenditures than the observed quantities of 162 hours of machinery use and $223 expenditure on hired labor for pruning.

Table 3.6 Mean Isoquant and Marginal Rates of Substitution for Machinery and Labor in Apple Pruning (Model VII-A)

Isoquant (Combination of hours of machinery use and hired labor to prune an average of 1,229 trees: Input of machine use [hours use of $1,000 value of equipment, (X_1)] Geometric mean, $\bar{X}_1 = 162$	Quantity of labor in dollar value, (X_3) Geometric mean, $\bar{X}_3$ = $222.65	Marginal Rate of Substitution of Machinery Use for Labor
(hours)	(dollars)	
40	3,486	171.32
60	1,571	51.47
80	892	21.92
100	575	11.31
110	477	8.53
120	402	6.59
130	343	5.19
140	297	4.17
150	259	3.39
160	228	2.80
170	203	2.34
180	181	1.97
190	163	1.69
200	147	1.45
220	122	1.09
240	103	0.84
260	88	0.66
280	76	0.53
300	66	0.43

Apple Tillage and Spraying Operations

Satisfactory production functions could not be developed for the tillage and spraying operations from the survey data. The high correlations between the categories of inputs indicated that the categories of inputs were basically complements or substitutes in the production process. It was also difficult to develop an appropriate independent variable (output) for the production function fitting. The output from the labor and machinery used in the tillage and spraying operations was neither total sales nor the number of trees on which the operation was performed. The operations were performed on a predetermined number of trees (usually all of the bearing trees). For these reasons no production functions are presented for the tillage and spraying operations.

Summary

Resource productivity in apple production was examined through production function analysis. Equations were fitted at the enterprise level and for two major operations within the enterprise, i.e., pruning and harvesting.

The enterprise and harvest operation production functions were fitted with total sales as the dependent variable. The pruning operation was fitted with the total number of trees upon which the operation was performed as the dependent variable.

Among the independent variables that were used, hours of machinery use, trees, and hired labor were found to have the greatest explanatory power and were significant in every production function in which they were included. The marginal value products of these variables were also higher than the factor cost in most equations. The independent variables, custom operations and family labor, were not significant in any of the equations reported.

At the enterprise level (Model I-A) there was no indication of other than constant returns to scale in apple production. Also the apple harvesting function had a sum of elasticities which was not significantly different from one. The pruning regression had a sum of elasticities which was significantly less than one.

Examination of isoquant relationships between hired labor and machinery use indicated substantial increases in machinery use accompanied by decreases in hired labor use in order to reach the least cost combination of the two resources for the enterprise, harvest, and pruning operation production functions. In the tillage and spraying operations the results of the production function analysis were unsatisfactory. There was evidence of strong complementarity between labor and machinery use in these two operations which prevented further analysis with the Cobb-Douglas production function.

CHAPTER IV

TART CHERRY PRODUCTION FUNCTIONS

The data for the tart cherry production functions were obtained from the sample of 258 farms described in Chapter I. The data for tart cherries were limited to reasonably homogeneous blocks of bearing tart cherry orchards. As with apples, the information obtained for tart cherries consisted of a chronological enumeration of inputs of labor and machinery in the production of tart cherries in 1966. The variables for the production function analysis were developed from this data.

There were a total of 68 usable schedules obtained for tart cherry production at the enterprise level. All of the production functions in this Chapter are for tart cherries although they may be simply called "cherry" functions for brevity.

Cherry Enterprise Functions

Description of the Variables

In general the variables for the tart cherry enterprise functions were formulated in the same manner as the variables for the apple production functions reported in Chapter III. The variables are described below for the cherry production functions.

Value of Production

The dependent variable is the total value of fruit sold from the orchard in 1966. The total value was obtained by multiplying the production by the farm price of $280 per ton for tart cherries.

Number of Trees

The number of trees per observation, i.e., per orchard was used as a factor of production. The number of trees was considered a better measure of the input than the acres of orchard because it measures the variation between orchards better.

Hours Use of $1,000 Value of Equipment

As explained in Chapter III, the machinery input was developed from information on the schedules and standardized to obtain the hours of use of $1,000 value of equipment.

Custom Operations

This is the measure of the inputs purchased by the farmer for those operations such as pruning, spraying, and harvesting that were performed on a custom operation basis or for which custom equipment was rented. The variable is expressed in terms of dollar expenditure.

Family Labor

The hours of direct family labor input as recorded by operations performed is used as an input variable. No discrimination was made between types of labor, i.e., operator, wife, or other family.

Hired Labor

The dollar cost of hired labor was recorded for each operation and aggregated for the enterprise. A sizable quantity of hired labor was used in the harvest operation and received a piece-rate wage making it impossible to use hours of hired labor as an input.

The Function for Total Sales (Model I-C)

The Regression Fitting

This function was fitted to the entire sixty-eight observations that were available for cherry enterprise functions.

The regression was of the form:

$$\hat{Y}_1 = a\, X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5}$$

Where:

$\hat{Y}_1$ = the estimate of sales per orchard in 1966;

a = constant;

b_i = estimate of the regression coefficient associated with the i^{th} variable;

X_1 = number of trees per orchard in 1966;

X_2 = hours of use of \$1,000 value of equipment in the orchard in 1966;

X_3 = dollars spent on custom operations in the orchard in 1966;

X_4 = hours of family labor used in production in 1966; and

X_5 = dollars spent for hired labor in production in 1966.

The computed regression equation was:

$$\hat{Y}_1 = 24.224 \; X_{1(0.1085)}^{0.4033***} \; X_{2(0.1028)}^{0.2276**} \; X_{3(0.0384)}^{0.0362} \; X_{4(0.0372)}^{-0.0141} \; X_{5(0.0515)}^{0.2102***}$$

The coefficient of multiple determination, R^2, was .70.

The adjusted coefficient of multiple determination, $\bar{R}^2$, was .67.

The coefficient of multiple determination of .70 indicates that 70 percent of the variation in crop income was associated with changes in the specified input quantities. The sum of the elasticities (Σb_i) was 0.89 which is not significantly different from 1. The coefficients for trees, machinery use, and hired labor were significant. Custom operations and family labor were not significant at levels as low as 10 percent. The b values for the three significant inputs have a sum of elasticities of .84 indicating an .84 percent increase in output for a one percent increase in each of these inputs.

Marginal Value Products

The marginal value products of the inputs are shown in Table 4.1. The marginal value product of $2.20 per tree can be viewed as the annual return attributable to adding an additional bearing cherry tree. The average number of trees per acre for the sample was 93. The younger trees are generally on 20 x 20 spacing with an average of 100 trees per acre.

Table 4.1 Marginal Productivities at Mean Input Levels for Cherry Enterprise Function (Model I-C)

Input Category	Geometric Mean	Marginal Value Product at Geometric Mean
Trees	2,252 trees	$2.20 per tree
Machinery	775 hours	$3.60 per hour use
Custom operations[a]	$1.84	$241.53 per dollar
Family labor[b]	201 hours	0
Hired labor	$2,591	$0.99 per dollar

[a]Computed with b value which was not significant at 10 percent level.

[b]Negative b value would give negative MVP.

The marginal value product of an hour's use of $1,000 value of machinery was $3.60. This exceeds the estimated cost of $2.00 per hour of use of $1,000 value of machinery.

The MVP of custom operations was computed from a nonsignificant b value with a large variance. Therefore, it cannot be considered a reliable estimate of the marginal value product.

The MVP of family labor is assumed to be zero since the b coefficient for labor was negative and not significant. The MVP of $0.99 for hired labor indicates that it would not be profitable to add hired labor to the production process.

Production Isoquant

The cherry production function was used as the basis for estimating the data for Table 4.2. Included in the data are: (a) the combination of hours use of $1,000 machine value and dollar cost of hired labor that will produce the mean cherry production of $12,263, and (b) marginal rates of substitution between these factors.

Table 4.2 Mean Isoquant and Marginal Rates of Substitution for Machinery and Labor in Cherry Production (Model I-C)

Isoquant (Combinations of hours of machinery use and hired labor to produce average production of $12,263)		Marginal Rate of Substitution of Machinery Use for Labor
Input of machine use hours use of $1,000 value of equipment, (X_2)] Geometric mean, $\overline{X}_2$ = 775	Quantity of labor in dollar value, (X_5) Geometric mean, $\overline{X}_5$ = 2,591	
(hours)	(dollars)	
300	7,243	26.14
500	4,166	9.02
700	2,893	4.47
800	2,504	3.39
900	2,204	2.65
1,000	1,966	2.13
1,100	1,774	1.75
1,300	1,480	1.23
1,500	1,268	0.91
1,700	1,107	0.71

Assuming a price ratio of 2 and equating it with the marginal rate of substitution of machinery use and hired labor, we obtain the least cost combination of 1,034 hours of machinery use and $1,900 expenditure on hired labor. This is a reasonably large increase in machinery use and decrease in hired labor expenditures from the mean quantities of 775 hours of machinery use and $2, 591 expenditures on hired labor.

The Function for Sales per 100 Trees (Model IV-C)

The cherry production function with total sales as the dependent variable which was reported above, included the number of trees as a variable. In contrast, a function which is expressed in terms of inputs per 100 trees was developed. Each of the variables in Model I-C, except the number of trees, was divided by the number of 100 trees per orchard in order to develop the variables for Model IV-C.

This is the equivalent of forcing constant returns to scale upon the production function. Since the sum of coefficients in the total sales equation (Model I-C) indicated no significant difference from constant returns to scale, the coefficients for the variables in Model IV-C were essentially the same. The results of the fitting did not contribute enough to the analysis to merit more detailed discussion and are included in Appendix B.

Cherry Harvesting Operation Functions

The Function for Total Sales (Model VII-C)

The Regression Fitting

The regression was fitted to the same 68 observations to which the cherry enterprise functions were fitted.

The regression was of the form:

$$\hat{Y}_7 = a X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5}$$

Where:

$\hat{Y}_7$ = the estimate of sales per orchard in 1966;

a = constant;

b_i = estimate of the regression coefficient associated with the i^{th} variable;

X_1 = number of trees per orchard in 1966;

X_2 = hours use of $1,000 value of equipment in the harvesting operation in 1966;

X_3 = dollars spent on custom harvesting services;

X_4 = hours of family labor used in harvesting in 1966;

X_5 = dollars spent for hired labor in harvesting in 1966.

The computed regression equqtion was:

$$\hat{Y}_7 = 18.851 \; X_1^{\underset{(0.1117)}{0.5385^{***}}} \; X_2^{\underset{(0.0637)}{0.1167^{*}}} \; X_3^{\underset{(0.0374)}{0.0333}} \; X_4^{\underset{(0.0333)}{-0.0122}} \; X_5^{\underset{(0.0508)}{0.2157^{***}}}$$

The coefficient of multiple determination, R^2, was 0.73.

The adjusted coefficient of multiple determination, $\bar{R}^2$, was 0.71.

The sum of the elasticities of .89 was not significantly different from 1 at the 1 percent level. The elasticities for trees and hired labor were significant at the 1 percent level of probability. The elasticity of machinery use was significant at the 7 percent level. Neither family labor nor custom operations were significant at probability levels as low as 10 percent.

Marginal Value Products

The marginal value products of the inputs are shown in Table 4.3. The MVP of $2.81 for an additional bearing cherry tree can be viewed as the marginal annual return attributable to adding an additional bearing cherry tree on which the harvest operation would be performed.

The marginal value product was $5.44 for an additional hour's use of $1,000 value of machinery. The MVP is considerably larger than the $2.00 cost of machinery use assumed earlier. So it appears that the use of machinery could be profitably expanded.

The MVP of custom operations is large, but it was calculated from a b value that was not significant which makes it unreliable. The b coefficient for family was also not significant.

The marginal value product of hired labor of $1.10 indicates that hired labor is returning more than its cost at the current level of use.

Table 4.3 Marginal Productivities at Mean Input Levels for Cherry Harvesting Function (Model VII-C)

Input Category	Geometric Mean	Marginal Value Product at Geometric Mean
Trees	2,350 trees	$2.81 per tree
Machinery	264 hours	$5.44 per hour
Custom operations	$1.82	$225.51 per dollar
Family labor[a]	61.7 hours	0
Hired labor	$2,405.41	$1.10 per dollar

[a]MVP assumed to be zero since b value is negative.

Production Isoquant

The cherry harvesting operation function was used as the basis for estimating the isoquant data of Table 4.4. Included in the data are: (a) the combination of hours of use of $1,000 value of machinery and dollars cost of hired labor used in the harvest operation to produce the mean cherry production of $12,263: and (b) marginal rates of substitution between these factors.

Assuming a cost of $2.00 per hour of use of $1,000 value of equipment commonly used in harvest operations and a cost of $1.00 for $1.00 of hired labor we obtain a price ratio of 2. Equating this price ratio with the marginal rate of substitution of machinery use and hired labor in the harvest operation, we obtain a combination of approximately 460 hours of machinery use and $1,780 expenditure on hired labor. This represents an increase of 196 hours of use of $1,000 value of machinery and a decrease of $625 hired labor from the mean combination.

The Function for Sales per 100 Trees (Model VIII-C)

As with the enterprise function, the inputs for the harvest operation regression function were deflated to a per 100 trees basis. Since the sum of the coefficients in the total sales equation (Model VII-C) indicated no significant difference from constant returns to scale, the coefficients for the variables in Model VIII-C were essentially the same. The results of the fitting did not contribute enough to the analysis to merit more detailed discussion and are included in Appendix B.

Table 4.4 Mean Isoquant and Marginal Rates of Substitution for Machinery and Labor in Cherry Harvesting (Model VII-C)

Isoquant (Combinations of hours of machinery use and hired labor to produce average production of $12,263)		Marginal Rate of Substitution of Machinery Use for Labor
Input of machine use [hours use of $1,000 value of equipment, (X_2)] Geometric mean, $\overline{X}_2$ = 263.63	Quantity of labor in dollar value, (X_5) Geometric mean, $\overline{X}_5$ = $2,405.41	
(hours)	(dollars)	
70	4,928	38.08
96	4,154	23.40
122	3,649	16.18
148	3,287	12.01
174	3,012	9.36
200	2,793	7.55
226	2,614	6.26
252	2,465	5.29
265	2,399	4.90
278	2,337	4.54
304	2,227	3.96
356	2,066	3.11
382	1,968	2.79
408	1,899	2.52
434	1,836	2.29
460	1,780	2.09
486	1,728	1.92
512	1,680	1.77

Cherry Pruning Function (Model IX-C)

The production function for the pruning operation was fitted using the number of trees upon which the operation was performed as the dependent variable.

The Regression Fitting

The pruning operation function was fitted to 63 observations. Five of the farmers producing cherries did not prune during 1966.

The regression was of the form:

$$Y_9 = a\, X_1^{b_1}\, X_2^{b_2}\, X_3^{b_3}$$

Where:

Y_9 = the estimate of the number of trees pruned per orchard in 1966;

a = constant;

b_i = estimate of the regression coefficient associated with the i^{th} variable;

X_1 = hours use of $1,000 value of equipment in the pruning operation;

X_2 = hours of family labor used in pruning in 1966;

X_3 = dollars spent for hired labor in pruning in 1966;

The computed regression was:

$$Y_9 = 254.43\; X_1{}^{0.3326***}_{(0.0777)}\; X_2{}^{0.0495}_{(0.0540)}\; X_3{}^{0.0647}_{(0.0433)}\;{}^{1}$$

The coefficient of multiple determination, R^2, was 0.36.

The adjusted coefficient of multiple determination, $\overline{R}^2$, was 0.33.

The sum of elasticities was 0.45 which was significantly different from one at the one percent level of probability. The elasticity of machinery use was significant at the 0.05 percent level. The elasticity of hired labor

[1]Coefficient b_3 significant at 14 percent level.

was significant at the 14 percent level. Family labor was not significant at probability levels as low as 35 percent.

Marginal Physical Products

The marginal physical products of the inputs are presented in Table 4.5. In order to compare the MPP of machinery use and hired labor, a price for machinery use was assumed to compute the MPP per dollar of machinery use. Assuming a price of $2.00 per hour use of $1,000 value of equipment, a value of 4.6 trees per dollar cost of machinery used was obtained. Therefore, the MPP of machinery use is 0.84 as large as the MPP of hired labor.

Table 4.5 Marginal Productivities at Mean Input Levels for Cherry Pruning Function (Model IX-C)

Input Category	Geometric Mean	Marginal Value Product at Geometric Mean
Machinery Use	42.3 hours	9.2 trees per hour
Family Labor[a]	48.4 hours	1.37 trees per hour
Hired Labor	$15.94	5.43 trees per dollar

[a]Computed from nonsignificant b coefficient.

Production Isoquant

The cherry pruning operation function was used as the basis for estimating the isoquant data of Table 4.6. Included in the data are: (a) the combination of hours use of $1,000 value of machinery and dollar cost of hired labor used in the pruning operation to prune the mean of 1,339 trees per farm, and (b) marginal rates of substitution between these factors.

Table 4.6 Mean Isoquant and Marginal Rates of Substitution for Machinery and Labor in Cherry Pruning (Model IX-C)

Isoquant (Combination of hours of machinery use and and hired labor to prune 1,339 trees)		Marginal Rate of Substitution of Machinery Use for Labor
Input of machine use [hours use of $1,000 value of equipment, (X_1)] Geometric mean, $\bar{X}_1$ = 48	Quantity of labor in dollar value, (X_3) Geometric mean, $\bar{X}_3$ = $15.93	
(hours)	(dollars)	
10	52,233	26,865.52
20	1,478	380.06
30	184	31.48
40	42	5.38
50	13	1.37
60	5	0.45
70	2	0.17
80	1	0.08
90	1	0.04

Assuming a cost of $2.00 per hour of use of $1,000 value of equipment commonly used in the pruning operation and a cost of $1.00 for $1.00 of hired labor, we obtain the least cost combination of approximately 48 hours use of $1,000 value of equipment and $15 of hired labor to prune the mean output of 1,339 trees which are the mean quantities currently being used.

Cherry Tillage and Spraying Operations

Satisfactory production functions could not be developed for the tillage and spraying operations from the survey data. High correlations between the categories of inputs indicated that all of the categories of inputs were basically complements or substitutes in the production process. It was also difficult to specify an appropriate independent variable (output) for the production function fitting. The output from the labor and machinery used in the tillage and spraying operations was neither total sales nor the number of trees on which the operation was performed. The operations were performed on a predetermined number of trees (usually all of the bearing trees). For these reasons no production functions are presented for the tillage and spraying operations.

Summary

Resource productivity in cherry production was examined through production function analysis. Equations were fitted at the enterprise level and for two major operations within the enterprise, i.e., pruning and harvesting.

The enterprise and harvest operation production functions were fitted with total sales as the dependent variable. The pruning operation was fitted with the total number of trees upon which the operation was performed as the dependent variable.

Among the independent variables that were used, hours of machinery use, trees, and hired labor were found to have the greatest explanatory power and were significant in every production function in which they were included. The independent variable, family labor, was not significant in any equation. Likewise, expenditures for custom operations was not significant in any equation.

At the enterprise level (Model I-C) there was no indication of other than constant returns to scale in cherry production. Also the cherry harvesting function (Model VII-C) had a sum of elasticities which was not significantly different from one. As reported earlier for apples, the pruning regression for cherries had a sum of elasticities which was significantly less than one.

Examination of isoquant relationships between hired labor and machinery use indicated substantial increases in machinery use accompanied by decreases in hired labor use in order to reach the least cost combination of the two resources for the enterprise and harvest operation functions. In the pruning operation there was no change indicated from the observed mean combinations of machinery use and hired labor.

CHAPTER V

APPLE ENTERPRISE ADJUSTMENT POSSIBILITIES

The apple production function analysis of Chapter III indicated there was substantial potential for substituting machinery use for hired labor in the production process. This was true in the enterprise function (Model I-A) and pruning and harvesting operations (Models V-A and VII-A). In each of these functions, the least cost combination of machinery use and hired labor for producing apples indicated movement along the isoquant from the observed mean combination of machinery use and hired labor to a combination of more machinery use and less hired labor to perform the operations in apple production.

Analysis of the production techniques used for apples in Chapter III indicated that many apple farmers were currently using the available labor saving techniques. The labor replaced by using the two best labor saving techniques currently available--a hydraulic pruning platform and a forklift to handle the fruit--is relatively small compared to the labor use remaining in the hand harvest operation.

In order to evaluate the potential for reduction of labor use in apple production, four basic budgets were constructed. The impact on production costs of increasing labor costs in each budget was examined.

Production techniques that are approximately the same as those used in apple production on the majority of fruit farms in Michigan were assumed for the standard apple enterprise budgets. The advanced apple enterprise budgets assume the use of labor saving production techniques that are available to apple farmers at the current time and the mechanical apple harvester which may be available by the 1969 season. The mechanical apple harvester was included because it has the greatest potential for reducing labor inputs in apple production. Examination of these budgets gives an indication of the potential for adjustment in the apple enterprise in 1969-1970. The budgets compare the relative profitability of continuing essentially the present technologies and adopting the newest techniques of production.

The basic farm situation assumed for sets of budgets is the same. In the first set of budgets the farm has 60 acres of bearing fruit, 25 of which are apples. Hill determined that there was an average of 59 acres of fruit (bearing and nonbearing) in the area sample of 85 farms in 1966. Fifty-six percent of the farms had apple orchards with an average acreage of 24 acres with 22 acres of bearing trees.[1] On the basis of this data, it seems appropriate to assume 60 acres of bearing fruit and 25 acres of apples as a representative farm situation for the 1969-1970 period. The acreage figures reported by Hill were developed from the same farms from which the data for the production functions of Chapters III and IV were

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[1]Hill, Resource Use and Returns on Michigan Fruit Farms, p. 11.

developed. In the sample of 169 large farms there were 139 acres of fruit (bearing and nonbearing) and 73 acres (63 acres bearing) of apples. Therefore, the second pair of budgets were developed for 70 acres of apples and 140 acres of fruit. In each case the remaining acreage of fruit is assumed to be composed primarily of cherries in combination with one or more other fruits.

Estimating the total revenue for the apples produced in each budget was rather difficult. For comparability the apples harvested should be valued at the field run price. Packing operations are not included in the budgeted production process since they are essentially transformations of the harvested product to another product. The average price received by farmers at the first point of sale for the years 1964-67 was $1.75 per bushel.[2] This price includes some packaging services performed by the farmer. Ninety percent ($1.57) of the price at the first point of sale was taken as the value of field run apples that were hand harvested.

The raw product resulting from hand and machine picking are not of the same quality. The hand harvested apples normally are separated for fresh sales and processing sales. All of the apples harvested by mechanical harvesters are assumed to be used for processing because bruising which occurs with mechanical harvesting prevents fresh market sales of the apples. The apples from mechanical harvesting should be of higher quality than the average apples going to processing from hand harvesting. Some processing apples from hand harvesting are the rejects from fresh sales while the mechanically harvested apples include the high

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[2]Michigan Department of Agriculture, Michigan Agricultural Statistics, (Lansing, Michigan, July 1968), p. 17.

quality apples which could normally be sold for fresh sales.

The average price (at the processing plant door) of all processed apples in Michigan was $46.92 per ton ($1.13 per bushel) for the 1964-67 period. The average price (at the processing plant door) for apples used in canning and freezing in Michigan was $63.30 per ton ($1.52 per bushel) for the 1964-67 period.[3] It is assumed that after discounting for bruising the average price for mechanically harvested apples should be only about 10 percent lower than the average price of apples used for canning and freezing. Based on the average price of the most recent four years (1964-67) of $1.52 per bushel, this would result in a price of $1.37 per bushel. This price will be used for mechanically harvested apples in the budgets.

Since the price of mechanically harvested apples is lower than hand harvested apples, the costs of production must be reduced by at least the amount of the price differential by mechanization in order for it to be a profitable adjustment for the farmer.

Budgets for the 25 Acre Apple Orchard

All machinery which is not specialized to apple production is budgeted to reflect use in the other fruit enterprises by allocation of fixed costs according to the proportion of the total fruit acreage (42 percent) which is apple orchard in Budgets I-A, II-A, III-A, and IV-A. The budgets include all of the costs incurred during the production process from pruning through

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[3] U. S. Department of Agriculture, Agricultural Prices, Supplement No. 1, Part II--Noncitrus Fruit Prices by States, 1964-67. (Washington, D.C.: June 1968), p. 4.

delivery of the fruit to the processor or storage. Any packing or storage process alters the form of the harvested product and was not included in the budgets. The production functions of Chapter III did not include transportation from the field to the processor or storage.

The budgets were developed primarily from the following sources: the data obtained for apple production functions presented in Chapter III; earlier published and unpublished work in Michigan by O. F. Buller; data from New York cost and return farm accounts, and; machinery and operating costs from Conner, et. al.[4] The information contained in these sources was supplemented by consultation with professionals working closely with fruit production in Michigan.

Standard Apple Enterprise Budget I-A

The apple orchard is assumed to have only bearing trees with an average age of 20 years. The machinery and equipment used in the enterprise is assumed to have a present value of one-half of the new replacement cost unless noted otherwise.

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[4] O. F. Buller and M. P. Kelsey, "Labor Inputs, Crop Costs and Returns for Michigan Tree Fruits," Agricultural Economics Mimeograph No. 34. (East Lansing, Michigan: Department of Agricultural Economics, Michigan State University, December 1965) pp. 3-6. O. F. Buller, "Profitable Adjustments on Selected Michigan Tree Fruit Farms," (unpublished Ph.D. dissertation, Michigan State University), 1965. C. D. Kearl and Darwin P. Snyder, Cash Crops and Fruits, Costs and Returns from Farm Cost Accounts--43 Farms, 1966, Ag. Econ. Res. No. 236, (Ithaca, New York: Cornell University, January 1968) pp. 6-7. Larry J. Conner, et. al., Michigan Farm Management Handbook, Agricultural Economics Report No. 36, (East Lansing, Michigan: Department of Agricultural Economics, Michigan State University, 1967), pp. 27-28.

Specification of Production Techniques

Pruning.--The pruning operation includes shaping of the bearing surface of the tree through removal of selected growth and disposal of the pruned limbs. The pruning is assumed to be done with hand tools and a chainsaw. Ladders are used to reach the upper portions of the tree. Any large limbs are piled for burning while the smaller limbs are chopped up with the rotary mower.

Tillage.--Controlling weeds and grass is accomplished by spraying a band under the trees with a chemical weed killer. A rotary mower is used to mow the grass and weeds in the "middles" between the trees. Spraying reduces the competition of the tree with the weeds and grass for fertilizer and moisture. This program will maintain sod which will support mechanical equipment used in spraying and harvest operations.

Spraying.--Insecticide application is by a tractor drawn speed sprayer with an auxiliary motor and a 500 gallon tank. It is assumed that the farmer sprays a dilute or 2x spray mixture which requires more water per pound of chemical applied per acre than the 4x concentration sprays. This requires more time for repeated filling of the sprayer than the use of a 4x concentration. Twelve applications of chemicals were assumed.

Harvesting.--The apples are assumed to be picked entirely by hand. The apples are placed in bulk boxes (18 to 20 bushels) which are loaded onto a truck in the field by a tractor and forklift.

Miscellaneous.--The miscellaneous operation consists of fertilization with a tractor and spreader, orchard clean-up operations, mouse baiting, and occasional hand thinning.

Budgeting Results

In Budget I-A the basic cash wage level is assumed to be $1.50 per hour for hired labor. Social security payments of 4.4 percent and workmen's compensation costs of $4.40 per $100 make the cost to the farmer $1.63 per hour.

The piecework payment of $.30 per bushel gives an hourly equivalent wage of $2.55 to the worker of average productivity according to worker productivity studies conducted in 1966.[5] A piecework wage of $.25 per bushel would give a worker of average productivity an hourly wage of $2.13. The wage of $.25 per bushel appeared to be approximately the average wage paid in 1966 by the farmers from whom the data was obtained for the apple production functions. In light of piecework wages observed in 1968, $.30 per bushel would appear to be the minimum estimate of the average piecework rate for picking apples in 1969-70. All other harvesting labor is priced at $2.50. Apple picking is primarily performed by male workers over 18 years of age. The work is rather strenuous which restricts many women from picking. In addition, the majority of apple picking is done

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[5]Jack L. Hervey, Charles M. Cuskaden, and Daniel W. Sturt, Worker Productivity in Selected Tree Fruit Harvesting, Report No. 11, Rural Manpower Center (East Lansing, Michigan: Rural Manpower Center, Michigan State University, September 1967), p. 14.

after public schools open in the fall which excludes most males under 18 years of age from the work force.

The adult worker of average productivity picked 8.6 bushels of apples per hour of gross time in the field in the 1966 productivity studies.[6] Using the estimate of the average field run price from 1964-1967 of $1.57 per bushel the value of product picked per worker per hour was $13.50.

The comparable figure for tart cherry productivity is 1.65 lugs per hour for the adult worker of average productivity.[7] Using average 1964-67 farm price of $.105 per pound total value of product picked per worker per hour is $4.68.[8] The value of product picked per worker per hour is 2.9 times larger in apples than tart cherries. Assuming that other costs of production for apples are only slightly higher than costs of production for cherries, it appears that apple producers can pay higher wages for harvest labor and continue to make a profit due to the relatively higher labor productivity in apple harvesting. This is consistent with the observed piece rates for cherries in 1966 of $.80 to $.85 per lug which gave a $1.32 to $1.40 hourly wage to the adult worker of average productivity compared to $2.13 per hour for apples.

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[6]<u>Ibid.</u>

[7]Jack L. Hervey, Charles M. Cuskaden, and Daniel W. Sturt, <u>Worker Productivity in Sweet and Tart Cherry Harvesting</u>, Report No. 5, Rural Manpower Center (East Lansing, Michigan: Rural Manpower Center, Michigan State University, February 1967), p. 21.

[8]<u>Michigan Agricultural Statistics</u>, September 1967, p. 16. <u>Michigan Agricultural Statistics</u>, July 1968, p. 17.

The results of Budget I-A in Table 5.1 show that harvest and pruning operations required the most hired labor per acre with $147.20 and $32.60, respectively, of the total $201.81 spent on hired labor. Seventy-three percent of the total labor bill is spent on the harvest operation making it the primary source of potential reduction in labor use through mechanization. Nonlabor expenses make total variable expenses $319.35 per acre. The addition of fixed expenses in the form of depreciation and interest on equipment of $51.92 gives a total production cost of $371.27 per acre or $.93 per bushel.

Apple Enterprise Budget II-A

Specification of Production Techniques

The production techniques are the same as those of Budget I-A with the exception of the adoption of a mechanical pruner for the pruning operation. Only the pruning operation will be described in detail at this time.

Pruning is accomplished by the use of a hydraulic boom with an attached working platform. The platform can be moved by the worker to position himself near the area of the tree to be pruned. The worker uses hydraulic power pruners to make the pruning cuts. The hydraulic system of the pruner is power by the hydraulic system of the tractor. Brush removal is accomplished by burning large limbs and shredding the remaining limbs with a brush chopper.

Budgeting Results

In Budget II-A (Table 5.3), the addition of mechanical pruning to the standard production techniques of Budget I-A produces a decrease in production

Table 5.1 Budget for Production of Apples with Standard Techniques of Production and 400 Bushel Yield with 25 Acres of Apple Orchard (Budget I-A)[a]

Item	Unit	Quantity	Price (dollars)	Amount (dollars)
	Requirements Per Acre			
Variable Expenses				
Pruning				
(1) Hand pruning equipment, chain saw, and ladder	hours	18	0.20	3.60
(2) Tractor	hours	1	1.00	1.00
(3) 7' Rotary mower	hours	1	0.45	.45
(4) Labor--pruning, clear brush	hours	20	1.63	32.60
Tillage				
(1) Tractor	hours	2.0	1.00	2.00
(2) Sprayer (weed)	hours	0.50	0.45	0.68
(3) Spray material simozine and arnitral	pounds	3.5	2.85	10.00
(4) Mower 7'	hours	1.5	0.45	0.68
(5) Labor	hours	2.00	1.63	3.26
Spraying				
(1) Sprayer 500 gallon	hours	4.5	2.75	12.38
(2) Tractor	hours	4.5	1.00	4.50
(3) Labor	hours	6.5	1.63	10.60
(4) Spray materials 12 applications				56.00
Harvesting				
(1) Harvest hand equipment and ladders		4.0	0.10	0.40
(2) Harvest labor 400 bu. @ $.30/bu.	--	--	--	120.00

Table 5.1 (cont'd.)

Item	Unit	Requirements Per Acre Quantity	Price	Amount
Variable expenses			(dollars)	(dollars)
Harvesting (cont'd.)				
(3) Trucking	miles	80	0.12	9.60
(4) Harvest loading and hauling	hours	10	2.72	27.20
(5) Tractor and forklift	hours	5.00	1.20	6.00
Miscellaneous				
(1) Fertilizer--clean up--hand thinning		5	1.63	8.15
(2) Fertilizer spreader	hours	1	0.25	0.25
(3) Fertilizer 300 pounds	pounds	300	3.00/100	9.00
(4) Tractor	hours	1	1.00	1.00
Total variable cost				
Labor			201.81	
Nonlabor			117.54	
				319.35
Fixed cost (depreciation and interest)				51.92
Total cost				371.27
Cost per bushel				0.93/bushel
Total revenue (400 bushel @ $1.57)				628.00
Net return to land, management and nonequipment overhead				256.73

[a]Sixty acres of bearing fruit with 25 acres of apples assumed.

Table 5.2 Inventory of Equipment Investments with Standard Techniques of Production Assumed in Budget I-A

	New replacement cost (dollars)	Present Value (dollars)	Total useful life (years)	Annual depreciation (dollars)	Interest @ 6 percent (dollars)	Interest + depreciation (dollars)	Cost share for apples[a] (dollars)	Cost per acre (dollars)
Sprayer	4,000	2,000	10	400	120.00	520.00	286.00[b]	11.44
Tractor	4,500	2,250	10	450	135.00	585.00	245.70	9.83
Tractor	4,500	2,250	10	450	135.00	585.00	245.70	9.83
Hand pruning equipment	270	135	10	27	8.10	35.10	14.74	0.59
7' rotary mower	600	300	10	60	18.00	78.00	32.76	1.31
Sprayer (weed)	250	125	10	25	7.50	32.50	13.65	0.55
Forklift	1,000	500	10	100	30.00	130.00	54.60	2.18
Ladders	450	225	4	112	13.50	125.50	52.71	2.11
Picking bags, etc.	150	75	6	25	4.50	29.50	29.50	1.18
Fertilizer spreader	325	162	10	33	9.72	42.72	17.94	0.72
Truck	3,500	1,750	15	233	105.00	338.00	141.96	5.68
Bulk boxes	1,250	625	10	125	37.50	162.50	162.50	6.50
Total	20,795	10,397				2,663.82	1,297.76	51.92

[a]Cost share for equipment used in production of other fruits is 42 percent of total of interest plus depreciation unless otherwise noted.

[b]Due to more spray applications in apples than cherries which make up the bulk of remaining acreage, depreciation and interest assumed to be 1.4 times as large per acre of apples as other fruit.

Table 5.3 Budget for Production of Apples with Standard Techniques of Production Plus Mechanical Pruning and 400 Bushel Yield with 25 Acres of Apple Orchard (Budget II-A)[a]

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable Expenses				
Pruning				
(1) Wishbasket power pruner	hours	7.00	0.55	3.85
(2) Tractor 3-plow	hours	8.00	1.00	8.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor--pruning, clear brush	hours	10.00	1.63	16.30
Tillage				
(1) Tractor	hours	2.0	1.00	2.00
(2) Sprayer (weed)	hours	0.50	0.45	0.68
(3) Spray material simazine	pounds	3.5	2.85	10.00
(4) Mower 7'	hours	1.5	0.45	0.68
(5) Labor	hours	2.00	1.63	3.26
Spraying				
(1) Sprayer 500 gallon	hours	4.5	2.75	12.38
(2) Tractor	hours	4.5	1.00	4.50
(3) Labor	hours	6.5	1.63	10.60
(4) Spray materials 12 applications				56.00
Harvesting				
(1) Harvest hand equipment and ladders		4.0	0.10	0.40
(2) Harvest labor 400 bu. @ $.30/bu.	--	--	--	120.00

Table 5.3 (Cont'd.)

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Harvesting (cont'd.)				
(3) Trucking	miles	80	0.12	9.60
(4) Harvest loading and hauling	hours	10	2.72	27.20
(5) Tractor and forklift	hours	5.00	1.20	6.00
Miscellaneous				
(1) Fertilizer--clean up--hand thinning		5	1.63	8.15
(2) Fertilizer spreader	hours	1	0.25	0.25
(3) Fertilizer 300 pounds	pounds	300	3.00/100	9.00
(4) Tractor	hours	1	1.00	1.00
Total variable cost				
Labor			185.51	
Nonlabor			124.79	
				310.30
Fixed cost (depreciation and interest)				56.10
Total cost				366.40
Cost per bushel				0.92/bu.
Total revenue 400 bu. @ $1.57				628.00
Net return to land, management and nonequipment overhead				261.60

[a]Sixty acres of bearing fruit with 25 acres of apples assumed.

Table 5.4 Inventory of Equipment Investments with Standard Techniques of Production Plus Mechanical Pruning Assumed in Budget II-A

	New replacement cost (dollars)	Present value (dollars)	Total useful life (years)	Annual depre-ciation (dollars)	Interest @ 6 percent (dollars)	Interest + depre-ciation (dollars)	Cost share for apples[a] (dollars)	Cost per acre (dollars)
Sprayer	4,000	2,000	10	400	120.00	520.00	286.00[b]	11.44
Tractor	4,500	2,250	10	450	135.00	585.00	245.70	9.83
Tractor	4,500	2,250	10	450	135.00	585.00	245.70	9.83
Wishbasket pruner	1,833	916	8	229	55.00	284.00	119.26	4.77
7' rotary mower	600	300	10	60	18.00	78.00	32.76	1.31
Sprayer (weed)	250	125	10	25	7.50	32.50	13.65	0.55
Forklift	1,000	500	10	100	30.00	130.00	54.60	2.18
Ladders	450	225	4	112	13.50	125.50	52.71	2.11
Picking bags, etc.	150	75	6	25	4.50	29.50	29.50	1.18
Fertilizer spreader	325	162	10	33	9.72	42.72	17.94	0.72
Truck	3,500	1,750	15	233	105.00	338.00	141.96	5.68
Bulk boxes	1,250	625	10	125	37.50	162.50	162.50	6.50
Total	22,358	11,178				2,912.72	1,402.30	56.10

[a]Cost share for equipment used in production of other fruit is 42 percent of total of interest plus depreciation unless otherwise noted.

[b]Due to more spray applications in apples than cherries which make up the bulk of remaining acreage, depreciation and interest assumed to be 1.4 times as large per acre of apples as other fruit.

costs with no change in the product price. With a $1.50 cash wage and $.30 per bushel price rate harvesting wage, the cost of production of $0.92 per bushel which is $.01 per bushel less than the cost of production in Budget I-A with hand pruning using the same wage levels. Substituting mechanical pruning for hand pruning reduces labor costs by $16.30 per acre while other costs increase by $7.25 per acre. With higher wage levels the savings due to mechanical pruning would increase due to the reduction in man hours used per acre in pruning.

Advanced Apple Enterprise Budget III-A

This budget uses the most advanced techniques which will be available to apple producers by 1970. The most important change from Budgets I-A and II-A is the addition of a mechanical apple harvester. The use of all of these techniques in one budget produces a large reduction in labor use from the quantity used in Budget I-A.

Specification of the Production Techniques

Pruning.--Pruning is accomplished by the use of a hydraulic boom with an attached working platform. The platform can be moved by the worker to position himself near the area of the tree to be pruned. The worker uses hydraulic power pruners to make the pruning cuts. The hydraulic system of the pruner is powered by the hydraulic system of the tractor. Brush removal is accomplished by burning large limbs and shredding the remaining limbs with a brush chopper. Although tree hedgers have been used experimentally with savings in pruning labor, the hedger is not included in the budget. There is no conclusive evidence that there is a real savings of labor with the hedger. The tendency of undesirable growth patterns to develop after several years of hedging may require enough hand pruning to offset the labor savings of the initial years of pruning.

Tillage.--Controlling weeds and grass is accomplished by chemical weed control in combination with mowing as described for Budget I-A previously.

Spraying.--Pesticides are applied with a tractor drawn speed sprayer with an auxillary motor and a 500 gallon tank. It is assumed that the farmer sprays a 4x concentration spray. This reduces the time spent filling the sprayer with water due to the large amount of material applied per gallon of water relative to a dilute mixture.

Harvesting.--Harvesting is assumed to be done entirely with a mechanized harvester which consists of a mechanical shaker and catching frame. The harvester is a commercial model developed from the research conducted in New York by Cornell University and a private manufacturing firm. It is assumed that the harvester will be commercially available by 1969-70 seasons since commercial models have been manufactured on a trial production basis for two years.

The complete harvesting unit consists of two self-propelled catching frames--one for each side of the tree. A narrow deflector frame collects the fruit in the area between the two frames. An inertia-type shaker is mounted on each self-propelled half. The harvested fruit is conveyed into bulk boxes which are handled with a forklift. A four-man crew is used to harvest at a rate of approximately 200 bushels per hour.[9] This would replace 20 or more hand pickers of average productivity. Variation in the harvest capacity in bushels per hour will result with various yields per acre since the set-up time per tree is relatively invariate with yield per tree.

A gross operating time of three hours per acre is used for budgeting purposes. It was assumed that this will include some down time for machinery repairs and adjustments in the field.

Miscellaneous.--Only a small amount of labor (2.5 hours) is used in miscellaneous operations such as fertilization, mouse baiting, and general orchard cleanup operations.

Budgeting Results

In Budget III-A (Table 5.5) the cash wage level is assumed to be $1.50 for all operations other than the harvest operation. In the harvest operation a wage of $2.50 per hour is assumed for comparability to Budget I-A.

The reduction in expenditures on labor in harvesting and pruning operations from those in Budget I-A is rather large. Harvesting and pruning operations require $62.54 labor expenditure as contrasted with $179.80 in

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[9]Based on the author's interpretation of information obtained by letter and telephone from Professor E. D. Markwardt, Department of Agricultural Engineering, Cornell University and information from the following sources: E. D. Markwardt, et. al., "Mechanical Harvesting of Apples Used For Processing," (paper presented at the 1966 Annual Meeting of the North Atlantic Region--American Society of Agricultural Engineers, University Park, Pennsylvania, August 21, 1966), pp. 1-15. New York State Horticultural Society. Proceedings, 1967 Annual Meeting, (Rochester, New York, 1967), p. 51. New York State Horticultural Society. Proceedings, 1968 Annual Meeting, (Rochester, New York, 1968). pp. 81-84.

Table 5.5 Budget for Production of Apples with Advanced Techniques of Production and 400 Bushel Yield with 25 Acres of Apple Orchard (Budget III-A)[a]

Item	Unit	Quantity	Price	Amount
	Requirements Per Acre			
			(dollars)	(dollars)
Variable expenses				
Pruning				
(1) Wishbasket power pruner	hours	7.00	0.55	3.85
(2) Tractor 3-plow	hours	8.00	1.00	8.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor--pruning, clear brush	hours	10.00	1.63	16.30
Tillage				
(1) Sprayer 8" weed sprayer	hours	0.50	0.30	0.15
(2) 7' rotary mower	hours	1.50	0.45	0.68
(3) Tractor 3-plow	hours	2.00	1.00	2.00
(4) Labor	hours	2.00	1.63	3.26
(5) Spray materials simazine	pounds	3.50	2.85	10.00
Spraying				
(1) Sprayer 500 gallon	hours	3.80	2.75	10.45
(2) Tractor 3-plow	hours	3.80	1.00	3.80
(3) Labor	hours	6.00	1.63	9.78
(4) Spray materials 12 applications				56.00
Harvesting				
(1) Mechanical harvester	hours	3.00	1.50	4.50
(2) Harvest crew (4)	hours	12.00	2.72	32.64
(3) Truck	miles	80.00	0.12	9.60

Table 5.5 (Cont'd.)

Item	Requirements Per Acre			
	Unit	Quantity	Price	Amount
			(dollars)	(dollars)
Variable expenses				
Harvesting (cont'd.)				
(4) Labor--hauling	hours	5.00	2.72	13.60
(5) Tractor and forklift	hours	3.00	1.20	3.60
(6) Tractor and 3 pt. fork	hours	3.00	1.05	3.15
Miscellaneous				
(1) Fertilization, clean up labor	hours	2.50	1.63	4.07
(2) Fertilization, bulk spreader, $3/ton				0.45
(3) Fertilizer, 300 lbs.	pounds	300.00	3.00/100	9.00
Total variable cost				
Labor			79.65	
Nonlabor			125.68	
				205.33
Fixed cost (depreciation and interest)				328.63
Total cost				533.96
Cost per bushel				1.33/bu.
Total revenue 400 bushel @ $1.37				548.00
Net return to land, management and nonequipment overhead				14.04

[a]Sixty acres of bearing fruit with 25 acres of apples assumed.

Table 5.6 Inventory of Equipment Investment with Advanced Techniques of Production Assumed in Budget III-A

	New replacement cost (dollars)	Present value (dollars)	Useful life (years)	Annual depre-ciation (dollars)	Interest @ 6 percent (dollars)	Interest + depre-ciation (dollars)	Cost share for apples[a] (dollars)
Sprayer 500 gallon	4,000	2,000	10	400	120.00	520.00	286.00[b]
Tractor	4,500	2,250	10	450	135.00	585.00	245.70
Tractor	4,500	2,250	10	450	135.00	585.00	245.70
Wishbasket pruner	1,833	916	8	229	55.00	284.00	119.28
7' rotary mower	600	300	10	60	18.00	78.00	32.76
Weed sprayer	250	125	10	25	7.50	32.50	13.65
Forklift	1,000	500	10	100	30.00	130.00	54.60
3-pt. forklift	250	125	10	25	7.50	32.50	13.65
Truck	3,500	1,750	15	233	105.00	338.00	141.96
Mechanical harvester	30,000	30,000	5	6,000	900.00	6,900.00	6,900.00
Bulk boxes	1,250	625	10	125	37.50	162.50	162.50
Total	51,683	40,841				9,647.50	8,215.80

[a]Cost share for equipment used in production of other fruits is 42 percent of total of interest plus depreciation unless otherwise noted.

[b]Due to more spray applications in apples than cherries which make up the bulk of the remaining acreage, depreciation and interest are assumed to be 1.4 times as large per acre of apples as other fruits.

Budget I-A. The $46.24 spent on harvest labor in Budget III-A is approximately one-third as large as the $147.20 spent in Budget I-A. This savings in labor expenditure is offset by increased machinery depreciation and interest costs. Fixed costs are $328.63 per acre in Budget III-A and $51.92 per acre in Budget I-A. Total production costs are $533.96 per acre or $1.33 per bushel in Budget III-A.

Advanced Apple Enterprise Budget IV-A

The higher initial cost of the mechanical apple harvester resulted in rather large depreciation and interest costs in Budget III-A. Since there are prospects for harvesting other tree fruits with the harvester, the impact on production costs of allocating one half of the apple harvester investment to other crops within the farm was examined. The apple harvester has been used successfully on a limited basis for harvesting tart cherries after minor modifications and probably could be used for prune harvesting as well.

Specification of Techniques

The production techniques employed in Budget IV-A are identical with those in Budget III-A which were described earlier. The only difference in Budgets III-A and IV-A is the assumption that one half of the depreciation and interest costs of the mechanical harvester are allocated to other fruit crops in Budget IV-A.

Budgeting Results

In Budget IV-A (Table 5.7), the cash wage level is assumed to be $1.50 for all operations other than the harvest operation. In the harvest operation

Table 5.7 Budget for Production of Apples with Advanced Techniques of Production and 400 Bushel Yield with 25 Acres of Apple Orchard and Use of Harvester for Other Fruits (Budget IV-A)

Item	Requirement Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Pruning				
(1) Wishbasket power pruner	hours	7.00	0.55	3.85
(2) Tractor 3-plow	hours	8.00	1.00	8.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor--pruning, clear brush	hours	10.00	1.63	16.30
Tillage				
(1) Sprayer 8" weed sprayer	hours	0.50	0.30	0.15
(2) 7' rotary mower	hours	1.50	0.45	0.68
(3) Tractor 3-plow	hours	2.00	1.00	2.00
(4) Labor	hours	2.00	1.63	3.26
(5) Spray material simazine	pounds	3.50	2.85	10.00
Spraying				
(1) Sprayer 500 gallon	hours	3.80	2.75	10.45
(2) Tractor 3-plow	hours	3.80	1.00	3.80
(3) Labor	hours	6.00	1.63	9.78
(4) Spray materials 12 applications				56.00
Harvesting				
(1) Mechanical harvester	hours	3.00	1.50	4.50
(2) Harvest crew (4)	hours	12.00	2.72	32.64
(3) Truck	miles	80.00	0.12	9.60

Table 5.7 (Cont'd.)

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Harvesting (cont'd.)				
(4) Labor--hauling	hours	5.00	2.72	13.60
(5) Tractor and forklift	hours	3.00	1.20	3.60
(6) Tractor and 3 pt. fork	hours	3.00	1.05	3.15
Miscellaneous				
(1) Fertilization clean up labor	hours	2.50	1.63	4.07
(2) Fertilization, bulk spreader, $3/ton				0.45
(3) Fertilizer, 300 lbs.	pounds	300.00	3.00/100	9.00
Total variable cost				
Labor			79.65	
Nonlabor			125.68	
				205.33
Fixed cost (depreciation and interest: $4,765.80 ÷ 25)				190.63
Total cost				395.96
Cost per bushel				0.99/bu.
Total revenue				548.00
Net return to land, management and nonequipment overhead				152.04

Table 5.8 Inventory of Equipment Investment with Advanced Techniques of Production Assumed in Budget IV-A

	New replacement cost	Present value	Total useful life	Annual depre- ciation	Interest @ 6 percent	Interest + depre- ciation	Cost share for apples[a]
	(dollars)	(dollars)	(years)	(dollars)	(dollars)	(dollars)	(dollars)
Sprayer 500 gallon	4,000	2,000	10	400	120.00	520.00	286.00[b]
Tractor	4,500	2,250	10	450	135.00	585.00	245.70
Tractor	4,500	2,250	10	450	135.00	585.00	245.70
Wishbasket pruner	1,833	916	8	229	55.00	284.00	119.28
7' rotary mower	600	300	10	60	18.00	78.00	32.76
Weed sprayer	250	125	10	25	7.50	32.50	13.65
Forklift	1,000	500	10	100	30.00	130.00	54.60
3-pt. forklift	250	125	10	25	7.50	32.50	13.65
Truck	3,500	1,750	15	233	105.00	338.00	141.96
Mechanical harvester	30,000	30,000	5	6,000	900.00	6,900.00	3,450.00[c]
Bulk boxes	1,250	625	10	125	37.50	162.50	162.50
Total	51,683	40,841				9,647.50	4,765.80

[a]Cost share for equipment used in production of other fruits is 42 percent of total of interest plus depreciation unless otherwise noted.

[b]Due to more spray applications in apples than cherries which make up the bulk of the remaining acreage, depreciation and interest are assumed to be 1.4 times as large per acre of apples as other fruits.

[c]One-half of total of depreciation plus interest is allocated to apples.

a wage of $2.50 per hour is assumed for comparability to Budgets I-A, II-A, and III-A.

The reduction in machinery depreciation and interest costs make the cost of production much lower in Budget IV-A than Budget III-A. Fixed costs are $190.63 per acre in Budget IV-A and $328.63 per acre in Budget III-A. Total production costs are $395.96 per acre or $0.99 per bushel in Budget IV-A. This is a reduction in production costs of $0.34 per bushel from $1.33 per bushel in Budget III-A.

Even if one half of the depreciation and interest costs are allocated to other fruits, the net revenue per acre is lower with the addition of mechanical harvesting than without mechanical harvesting for the 25 acre orchard with a $1.50 cash wage and $.30 per bushel piece rate harvesting wage. The impact of increased wage levels will be analyzed in subsequent sections.

Effect of Higher Labor Costs

The effect of increasing the basic wage rate from $1.50 to $2.00 upon the budgets is illustrated in Table 5.9. At both wage levels the highest net revenue is obtained with Budget II-A (standard production techniques plus mechanical pruning). Even with one half of the depreciation and interest costs of the mechanical harvester allocated to other fruits net revenue from Budget IV-A is lower than that obtained from Budget II-A at both wage levels with a difference of $91.70 per acre at the $2.00 wage level.

Table 5.9 Costs and Returns Per Acre from Apple Production on 25 Acres of Orchard with Standard and Advanced Practices for Two Alternative Wage Levels[a]

Item	$1.50 Wage Level[b]			
	Standard Production Techniques Budget I-A	Standard Production Techniques Plus Mechanical Pruning Budget II-A	Advanced Production Techniques Budget III-A	Advanced Production Techniques Budget IV-A
	(dollars)	(dollars)	(dollars)	(dollars)
Variable expenses				
Labor	201.81	185.51	79.65	79.65
Nonlabor	117.54	124.79	125.68	125.68
Total	319.35	310.30	205.33	205.33
Fixed expenses				
Depreciation and interest	51.92	56.10	328.63	190.63
Total expenses	371.27	366.40	533.96	395.96
Total revenue	628.00	628.00	548.00	548.00
Net returns to management, land and nonequipment overhead	256.73	261.60	14.04	152.04

Table 5.9 (Cont'd.)

Item	Standard Production Techniques Budget I-A (dollars)	Standard Production Techniques Plus Mechanical Pruning Budget II-A (dollars)	Advanced Production Techniques Budget III-A (dollars)	Advanced Production Techniques Budget IV-A (dollars)
	$2.00 Wage Level[c]			
Variable expenses				
Labor	245.63	223.83	100.11	100.11
Nonlabor	117.54	124.79	125.68	125.68
Total	363.17	348.62	225.79	225.79
Fixed expenses				
Depreciation and interest	51.92	56.10	328.63	190.63
Total expenses	415.09	404.72	554.42	416.42
Total revenue	628.00	628.00	548.00	548.00
Net returns to management, land and nonequipment overhead	212.91	223.28	- 6.42	131.58

[a]Twenty-five acres of apple orchard with 400 bushel yield.

[b]Wage of $2.50 assumed for harvesting operation.

[c]Wage of $3.00 assumed for harvesting operation.

Budgets for Seventy-Acre Orchard

As mentioned earlier, the apple farms observed in the Large Farm sample have much larger average apple acreages than those in the Area Farm sample. The production costs per acre with a mechanical harvester are lowered significantly as the harvested acreage is increased by spreading the ownership costs of the harvester over a larger acreage. The representative farm size chosen includes 70 acres of bearing apples and has 140 acres of bearing fruit.

Four basic budgets are constructed which employ the same production techniques that were used for Budgets I-A, II-A, III-A, and IV-A. The basic complement of machinery is assumed to be used entirely for the 70 acres of apples with specified equipment assumed to be used equally on the entire 140 acres of fruit.

The productivity coefficients of labor and machinery are assumed to be the same as those in Budgets I-A, II-A, III-A, and IV-A. This is consistent with the lack of significant returns to scale in the apple enterprise functions of Chapter III.

Standard Apple Enterprise Budget V-A

The production techniques used in Budget V-A (Table 5.10) are the same as those described in Budget I-A. The hourly cash wage rate is $1.50 per hour for all operations other than harvesting. For harvesting the piece rate wage is $.30 per bushel and the hourly cash wage rate is $2.50 per hour.

Table 5.10 Budget for Production of Apples with Standard Techniques of Production and 400 Bushel Yield with 70 Acres of Apple Orchard (Budget V-A)[a]

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Pruning				
(1) Hand pruning equipment, chainsaw and ladder	hours	18	0.20	3.60
(2) Tractor	hours	1	1.00	1.00
(3) 7' rotary mower	hours	1	0.45	0.45
(4) Labor--pruning, clear brush	hours	20	1.65	32.60
Tillage				
(1) Tractor	hours	2.0	1.00	2.00
(2) Sprayer (weed)	hours	0.50	0.45	0.68
(3) Spray material simazine	pounds	3.5	2.85	10.00
(4) Mower 7'	hours	1.5	0.45	0.68
(5) Labor	hours	2.00	1.63	3.26
Spraying				
(1) Sprayer 500 gallon	hours	4.5	2.75	12.38
(2) Tractor	hours	4.5	1.00	4.50
(3) Labor	hours	6.5	1.63	10.60
(4) Spray materials 12 applications				56.00
Harvesting				
(1) Harvest hand equipment and ladders		4.00	0.10	0.40
(2) Harvest labor 400 bu. @ $.30/bu.	--	--	--	120.00
(3) Trucking	miles	80	0.12	9.60

Table 5.10 (Cont'd.)

Item	Unit	Quantity	Price	Amount
	Requirements Per Acre			
			(dollars)	(dollars)
Variable expenses				
Harvesting (cont'd.)				
(4) Harvest loading and hauling	hours	10	2.72	27.20
(5) Tractor and fork	hours	5.00	1.20	6.00
Miscellaneous				
(1) Fertilizer--clean-up--hand thinning	hours	5	1.63	8.15
(2) Fertilizer spreader	hours	1	0.25	0.25
(3) Fertilizer 300 pounds	pounds	300	3.00/100	9.00
(4) Tractor	hours	1	1.00	1.00
Total variable cost				
Labor			201.81	
Nonlabor			118.34	
				319.35
Fixed cost				
Depreciation and interest ($2,682.91 ÷ 70)				38.32
Total cost				357.67
Cost per bushel				0.89/bu.
Total revenue				628.00
Net returns to management, land, nonequipment overhead				270.33

[a]Seventy acres of apples on farm with total of 140 acres of bearing fruit.

Table 5.11 Inventory of Investments with Standard Techniques of Production Assumed in Budget V-A

	New replacement cost (dollars)	Present value (dollars)	Total Useful life (years)	Annual depre-ciation (dollars)	Interest @ 6 percent (dollars)	Interest + depre-ciation (dollars)	Cost share[a] (dollars)
Sprayer	4,000	2,000	10	400	120.00	520.00	520.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Hand pruning equipment	270	135	10	27	8.10	35.10	17.05
7' rotary mower	600	300	10	60	18.00	78.00	78.00
Sprayer (weed)	250	125	10	25	7.50	32.50	32.50
Forklift	1,000	500	10	100	30.00	130.00	65.00
Ladders	450	225	4	112	13.50	125.50	125.50
Picking bags, etc.	150	75	6	25	4.50	29.50	29.50
Fertilizer spreader	325	162	10	33	9.72	42.72	21.36
Truck	3,500	1,750	15	233	105.00	338.00	169.00
Bulk boxes	3,500	1,750	10	350	105.00	455.00	455.00
Total	23,045	9,772				2,956.32	2,682.91

[a]Hand pruning equipment, forklift, fertilizer spreaders, and trucks are assumed to be used equally on the 140 acres. The remaining complement of equipment is allocated exclusively to apple production.

Total variable costs per acre are $319.35. Fixed costs are $38.32 per acre which is slightly below the level of fixed costs in Budget I-A. Total cost per acre is $357.67 which is $.89 per bushel of apples. Total revenue is $628.00 which gives a net return of $270.33 per acre.

Apple Enterprise Budget VI-A

The addition of mechanical pruning is the only change in Budget VI-A from Budget V-A. The production techniques used in Budget VI-A (Table 5.12) are the same as those described for Budget II-A. The hourly cash wage rate is $1.50 per hour for all operations other than harvesting. For harvesting the piece rate wage is $.30 per bushel, and the hourly cash wage rate is $2.50 per hour.

Total variable costs per acre are $310.30. Fixed costs are $40.11 per acre which is slightly higher than the fixed costs of Budget V-A. Total cost per acre is $350.41 which is $0.88 per bushel of apples. Total revenue is $628.00 which gives a net return of $277.59 per acre. The net return for Budget VI-A is $7.26 per acre greater than Budget V-A which used hand pruning.

Table 5.12 Budget for Production of Apples with Standard Techniques of Production Plus Mechanical Pruning for 400 Bushel Yield with 70 Acres of Apple Orchard (Budget VI-A)[a]

Item	Requirements Per Acre Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Pruning				
(1) Wishbasket power pruner	hours	7.00	0.55	3.85
(2) Tractor 3-plow	hours	8.00	1.00	8.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor--pruning, clear brush	hours	10.00	1.63	16.30
Tillage				
(1) Tractor	hours	2.0	1.00	2.00
(2) Sprayer (weed)	hours	0.50	0.45	0.68
(3) Spray material simazine	pounds	3.5	2.85	10.00
(4) Mower 7'	hours	1.5	0.45	0.68
(5) Labor	hours	2.00	1.63	3.26
Spraying				
(1) Sprayer 500 gallon	hours	4.5	2.75	12.38
(2) Tractor	hours	4.5	1.00	4.50
(3) Labor	hours	6.5	1.63	10.60
(4) Spray materials 12 applications				56.00
Harvesting				
(1) Harvest hand equipment and ladders		4.0	0.10	0.40
(2) Harvest labor 400 bu. @ $.30/bu.	--	--	--	120.00
(3) Trucking	miles	80	0.12	9.60

Table 5.12 (Cont'd.)

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Harvesting (cont'd.)				
(4) Harvest loading and hauling	hours	10	2.72	27.20
(5) Tractor and fork	hours	5.00	1.20	6.00
Miscellaneous				
(1) Fertilizer--clean-up--hand thinning	hours	5.00	1.63	8.15
(2) Fertilizer spreader	hours	1.00	0.25	0.25
(3) Fertilizer 300 pounds	pounds	300	3.00/100	9.00
(4) Tractor	hours	1.00	1.00	1.00
Total variable cost				
Labor			185.51	
Nonlabor			124.79	
				310.30
Fixed cost				
Depreciation and interest ($2,807.86 ÷ 70)				40.11
Total cost				350.41
Cost per bushel				0.88/bu.
Total revenue				628.00
Net returns to management, land, and nonequipment overhead				277.59

[a]Seventy acres of apples on farm with total of 140 acres of bearing fruit.

Table 5.13 Inventory of Investments with Standard Techniques of Production Plus Mechanical Pruning Assumed In Budget VI-A

	New replacement cost	Present value	Useful life	Annual depre-ciation	Interest @ 6 percent	Interest + depre-ciation	Cost share[a]
	(dollars)	(dollars)	(years)	(dollars)	(dollars)	(dollars)	(dollars)
Sprayer	4,000	2,000	10	400	120.00	520.00	520.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Wishbasket pruner	1,833	916	8	229	55.00	289.00	142.00
7' rotary mower	600	300	10	60	18.00	78.00	78.00
Sprayer (weed)	250	125	10	25	7.50	32.50	32.50
Forklift	1,000	500	10	100	30.00	130.00	65.00
Ladders	450	225	4	112	13.50	125.50	125.50
Picking bags, etc.	150	75	6	25	4.50	29.50	29.50
Fertilizer spreader	325	162	10	33	9.72	42.72	21.36
Truck	3,500	1,750	15	233	105.00	338.00	169.00
Bulk boxes	3,500	1,750	10	350	105.00	455.00	455.00
Total	24,608	12,303				3,205.22	2,807.86

[a]Hand pruning equipment, forklift, fertilizer spreaders, and trucks are assumed to be used equally on the 140 acres. The remaining complement of equipment is allocated exclusively to apple production.

Advanced Apple Enterprise Budget VII-A

The production techniques used in Budget VII-A (Table 5.14) are the same as those described for Budget III-A. The hours cash wage rate is $1.50 for all operations other than harvesting. For harvesting the hourly cash wage rate is $2.50 and the piece rate is $0.30 per bushel.

Total variable costs are $205.33. Total labor cost is $79.65 compared with $201.81 for hand harvesting in Budgets V-A and VI-A. Much of this savings in labor cost is offset by fixed costs of $136.40 for Budget VII-A in comparison with $38.32 for Budget V-A and $40.11 for Budget VI-A. Total costs per acre are $341.73 which is $.85 per bushel. Total costs in this budget are $15.94 lower than hand harvesting. The lower price received for mechanically harvested fruit more than offsets this savings in production costs. Net revenue is $206.27 compared to $270.33 and $277.59 for Budgets V-A and VI-A, respectively.

Advanced Apple Enterprise Budget VIII-A

The production techniques employed in Budget VIII-A are identical with those of Budget VII-A which were described earlier. The only difference in Budgets VII-A and VIII-A is the assumption that one half of the depreciation and interest costs of the mechanical harvester are allocated to other fruit crops in Budget VIII-A.

Table 5.14 Budget for Production of Apples with Advanced Techniques of Production and 400 Bushel Yield With 70 Acres of Apple Orchard (Budget VII-A)[a]

Item	Requirements Per Acre Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Pruning				
(1) Wishbasket power pruner	hours	7.00	0.55	3.85
(2) Tractor 3-plow	hours	8.00	1.00	8.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor-- pruning, clear brush	hours	10.00	1.63	16.30
Tillage				
(1) Sprayer 8" weed sprayer	hours	0.50	0.30	0.15
(2) 7' rotary mower	hours	1.50	0.45	0.63
(3) Tractor 3-plow	hours	2.00	1.00	2.00
(4) Labor	hours	2.00	1.63	3.26
(5) Spray materials simazine	pounds	3.50	2.85	10.00
Spraying				
(1) Sprayer 500 gallon	hours	3.80	2.75	10.45
(2) Tractor 3-plow	hours	3.80	1.00	3.80
(3) Labor	hours	6.00	1.63	9.78
(4) Spray materials 12 applications				56.00
Harvesting				
(1) Mechanical harvester	hours	3.00	1.50	4.50
(2) Harvest crew (4)	hours	12.00	2.72	32.64
(3) Truck	miles	80.00	0.12	9.60

Table 5.14 (Cont'd.)

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Harvesting (con't.)				
(4) Labor-- hauling	hours	5.00	2.72	13.60
(5) Tractor and forklift	hours	3.00	1.20	3.60
(6) Tractor and 3 pt. fork	hours	3.00	1.05	3.15
Miscellaneous				
(1) Fertilization, clean up labor	hours	2.50	1.63	4.07
(2) Fertilization, bulk spreader, $3/ton	--	--	--	0.45
(3) Fertilizer, 300 lbs.	pounds	300.00	3.00/100	9.00
Total variable cost				
Labor			79.65	
Nonlabor			125.68	
				205.33
Fixed cost: Depreciation and interest ($9,547.75 ÷ 70)				136.40
Total cost				341.73
Cost per bushel				0.85/bu.
Total revenue				548.00
Net returns to management, land and nonequipment overhead				206.27

[a]Seventy acres of apples on farm with total of 140 acres of bearing fruit.

Table 5.15 Inventory of Equipment Investment with Advanced Techniques of Production Assumed in Budget VII-A

	New replacement cost (dollars)	Present value (dollars)	Useful life (years)	Annual depre- ciation (dollars)	Interest @ 6 percent (dollars)	Interest + depre- ciation (dollars)	Cost share (dollars)
Sprayer 500 gallon	4,000	2,000	10	400	120.00	520.00	520.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Wishbasket	1,833	916	8	229	55.00	284.00	142.00
7'rotary mower	600	300	10	60	18.00	78.00	78.00
Weed sprayer	250	125	10	25	7.50	32.50	32.50
Forklift	1,000	500	10	100	30.00	130.00	65.00
3-pt. forklift	250	125	10	25	7.50	32.50	16.25
Truck	3,500	1,750	15	233	105.00	338.00	169.00
Mechanical harvester	30,000	30,000	5	6,000	900.00	6,900.00	6,900.00
Bulk boxes	3,500	1,750	10	350	105.00	455.00	455.00
Total	53,933	41,966				9,940.00	9,547.75
							136.40/acre

[a]The wishbasket pruner, forklifts, and truck are assumed to be used equally on the 140 acres. The remaining complement of equipment is allocated exclusively to use in apples.

Total variable costs in Budget VIII-A (Table 5.16) are $205.33 per acre. Total fixed costs are $87.11 per acre. Total costs per acre are $292.44 or $0.73 per bushel giving a net revenue of $253.56 per acre. This is higher than the net revenue of $206.27 from Budget VII-A but lower than the net revenues of $270.33 and $277.59 of Budgets V-A and VI-A, respectively. The fixed costs in Budget VIII are still twice as large as those of the budgets with hand harvesting which offset the lower variable cost which result from reduced labor requirements.

Effect of Higher Labor Costs

Higher labor costs decrease the magnitude of the difference in net revenue between the budgets with hand harvesting and mechanical harvesting (Table 5.18). When the wage level is increased to $2.00 for nonharvest and $3.00 for harvest labor, the difference in the largest net revenue from hand harvesting (Budget VI-A) and mechanical harvesting (Budget VIII-A) is only $4.17 per acre.

The reduced labor requirements of mechanical harvesting keep total production costs with mechanical harvesting from rising as rapidly as total production costs with hand harvesting as wage levels increase.

Several factors could easily narrow the difference in net revenues even more. If the differential in the price for mechanically harvested apples was less, the net returns would be nearer the same. If the differential for apples harvested mechanically was decreased by only $.01 per bushel, there would be no difference in the net return per acre between Budgets VI-A and VIII-A.

Table 5.16 Budget for Production of Apples with Advanced Techniques of Production and 400 Bushel Yield with 70 Acres of Apple Orchard and Use of Harvester for Other Fruits (Budget VIII-A)

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variables expenses				
Pruning				
(1) Wishbasket power pruner	hours	7.00	0.55	3.85
(2) Tractor 3-plow	hours	8.00	1.00	8.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor--pruning, clear brush	hours	10.00	1.63	16.30
Tillage				
(1) Sprayer 8" weed sprayer	hours	0.50	0.30	0.15
(2) 7' rotary mower	hours	1.50	0.45	0.68
(3) Tractor 3-plow	hours	2.00	1.00	2.00
(4) Labor	hours	2.00	1.63	3.26
(5) Spray materials simazine	pounds	3.50	2.85	10.00
Spraying				
(1) Sprayer 500 gallon	hours	3.80	2.75	10.45
(2) Tractor 3-plow	hours	3.80	1.00	3.80
(3) Labor	hours	6.00	1.63	9.78
(4) Spray materials 12 applications	--	--	--	56.00
Harvesting				
(1) Mechanical harvester	hours	3.00	1.50	4.50
(2) Harvest crew (4)	hours	12.00	2.72	32.64
(3) Truck	miles	80.00	0.12	9.60

Table 5.16 (Cont'd.)

Item	Unit	Quantity	Price (dollars)	Amount (dollars)
	Requirements Per Acre			
Variable expenses				
Harvesting (cont'd.)				
(4) Labor--hauling	hours	5.00	2.72	13.60
(5) Tractor and forklift	hours	3.00	1.20	3.60
(6) Tractor and 3 pt. fork	hours	3.00	1.05	3.15
Miscellaneous				
(1) Fertilization, clean up labor	hours	2.50	1.63	4.07
(2) Fertilization, bulk spreader, $3/ton	--	--	--	0.45
(3) Fertilizer, 300 lbs.	pounds	300.00	3.00/100	9.00
Total variable cost				
Labor			79.65	
Nonlabor			125.68	
				205.33
Fixed cost				
(Depreciation and interest ($6,097.75 ÷ 70)				87.11
Total cost				292.44
Cost per bushel				0.73/bu.
Total revenue				548.00
Net returns to management, land and nonequipment overhead				253.56

Table 5.17 Inventory of Equipment Investment with Advanced Techniques of Production Assumed in Budget VIII-A

	New replacement cost (dollars)	Present value (dollars)	Useful life (years)	Annual depreciation (dollars)	Interest @ 6 percent (dollars)	Interest + depreciation (dollars)	Cost share[a] (dollars)
Sprayer 500 gallon	4,000	2,000	10	400	120.00	520.00	520.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Tractor	4,500	2,250	10	450	135.00	585.00	585.00
Wishbasket pruner	1,833	916	8	229	55.00	284.00	142.00
7' rotary mower	600	300	10	60	18.00	78.00	78.00
Weed sprayer	250	125	10	25	7.50	32.50	32.50
Forklift	1,000	500	10	100	30.00	130.00	65.00
3-pt. forklift	250	125	10	25	7.50	32.50	16.25
Truck	3,500	1,750	15	233	105.00	338.00	169.00
Mechanical harvester	30,000	30,000	5	6,000	900.00	6,900.00	3,450.00[b]
Bulk boxes	3,500	1,750	10	350	105.00	455.00	455.00
Total	53,933	41,966				9,940.00	6,097.75
							87.11/acre

[a]The wishbasket pruner, mechanical harvester, forklifts, and truck are assumed to be used equally on the 140 acres. The remaining complement of equipment is allocated exclusively to use in apples.

[b]One half of total depreciation plus interest is allocated to apples.

Table 5.18 Costs and Returns per Acre from Apple Production on 70 Acres of Orchard with Standard and Advanced Practices for Two Alternative Wage Levels[a]

$1.50 Wage Level[b]				
Item	Standard Production Techniques Budget V-A (dollars)	Standard Production Techniques Plus Mechanical Pruning Budget VI-A (dollars)	Advanced Production Techniques Budget VII-A (dollars)	Advanced Production Techniques Budget VIII-A (dollars)
Variable expenses				
Labor	201.81	185.51	79.65	79.65
Nonlabor	118.34	124.79	125.68	125.68
Total	319.35	310.30	205.33	205.33
Fixed expenses				
Depreciation and interest	38.32	40.11	136.40	87.11
Total expenses	357.67	350.41	341.73	292.44
Total revenue	628.00	628.00	548.00	548.00
Net returns to management, land and nonequipment overhead	270.33	277.59	206.27	253.56

Table 5.18 (Cont'd)

Item	Standard Production Techniques Budget V-A (dollars)	Standard Production Techniques Plus Mechanical Pruning Budget VI-A (dollars)	Advanced Production Techniques Budget VII-A (dollars)	Advanced Production Techniques Budget VIII-A (dollars)
	$2.00 Wage Level[c]			
Variables expenses				
Labor	245.63	223.82	100.11	100.11
Nonlabor	117.54	124.79	125.68	125.68
Total	363.17	348.62	225.79	225.79
Fixed expenses				
Depreciation and interest	38.32	40.11	136.40	87.11
Total expenses	401.49	388.73	362.19	312.90
Total revenue	628.00	628.00	548.00	548.00
Net returns to management, land and nonequipment overhead	226.51	239.27	185.81	235.10

[a]Seventy acres of apple orchard with 400 bushel yield.

[b]Wage of $2.50 assumed for harvesting operation.

[c]Wage of $3.00 assumed for harvesting operation.

Increasing the number of acres harvested will reduce the fixed cost per acre. Fixed costs per acre were reduced in Budget VIII-A by assuming that the harvester was used to harvest additional fruits on the farm, such as tart cherries.

An alternative method of reducing fixed costs to the farmer would be custom harvesting of apples or other fruits for other growers to spread fixed costs over larger acreages. Increases in wage levels above those used in the budgets would also narrow the net revenue difference from the standard techniques and advanced techniques due to smaller labor used with advanced techniques.

Potential Labor Adjustments

The budget analysis indicated that use of production techniques which included the mechanical harvester was nearly as profitable (two percent smaller net returns per acre) under the specified conditions as standard techniques plus mechanical pruning. Small changes in costs or revenue could make it more profitable to use those techniques which include the mechanical harvester. The adoption of these techniques at the individual farm firm level will have an effect on labor use at the industry (apple farms collectively) level.

The reduction in workers required to harvest apples is substantial. Although harvest rates of 200 bushels per hour have been observed, a sustained rate of 135 bushels per hour for a crew of four was assumed for budgeting purposes. A crew of approximately 17 pickers would be required to pick the same quantity per hour by hand if an average productivity of 8.6 bushels per hour, as observed in 1966 labor productivity studies, was assumed. The labor requirements are approximately one fourth as large with mechanical harvesting.

The direct impact on the apple grower is the substantial reduction in the number of workers he has to recruit and supervise during the harvesting operation. The large hired labor expenditures of the harvest operation were discussed in Chapter II. The harvest labor expenditures of $117.74 per acre were 82 percent of the total hired labor bill. Much less of the grower's total yearly labor input would be concentrated in the harvesting operation with mechanical harvesting. This would reduce the grower's dependence on seasonal labor. He could better utilize a small crew of full-time hired employees to perform most of the operations in apple production with minimal seasonal labor supplementation.

The total labor utilization in apple harvesting is illustrated by labor statistics of the Michigan Employment Security Commission. For the years 1964-1967 there was an average of 11,829 workers employed in apple harvesting at the peak harvest period (October 15), with sizable numbers employed from August 15 to November 15. Workers classified as "interstate" workers by the Michigan Employment Security Commission accounted for more than one half (6,949) of the workers employed in the peak period.[1] Adoption of mechanical harvesting would reduce dependence

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[1]Average of employment reported for that period for the years 1964 through 1967 as found in the annual publication of the Michigan Employment Security Commission, Michigan Farm Labor Report - Post Season 1964 (and subsequent years of 1965, 1966 and 1967).

upon this large quantity of seasonal migratory labor for the apple industry as a whole as well as reducing the quantity of local labor needed.

With the increasing mechanization of cherry harvesting, the reduction may become quite important to apple growers. Fewer interstate laborers will be attracted to the fruit production area as mechanization of fruit harvesting increases. The reduction of labor requirements in the harvest of one important fruit, such as tart cherries in July, decreases the continuous employment available for migrants in the area. This affects the availability of labor for harvesting of other crops, such as apples, which is the last fruit harvested in the season by migrants. Apple producers have complained in recent years about the increasing difficulty of finding qualified labor to harvest their crop. This situation is not likely to improve as long as there are low levels of unemployment in the general economy.

Summary

Earlier apple enterprise production function analysis (Chapter III) indicated that adjustments in the combinations of machinery and hired labor inputs should be made in order to reach the least-cost combination of resources for apple production. Partial budgeting was used to evaluate the production costs and returns from two sets of production techniques. The standard apple enterprise budgets employed the production techniques commonly used in apple production on Michigan farms. The advanced apple enterprise budgets employed the most advanced techniques available by 1969-70.

Production costs were determined for two basic farm situations of

25 acres and 70 acres of apple orchard. Two basic wage levels of $1.50 and $2.00 per hour were assumed to evaluate the impact of higher wage levels on the relative profitability of the two budgets.

With the 25-acre apple orchard the standard production techniques plus mechanical pruning (Budget II-A) gave the highest net return per acre at both wage levels. Although labor costs with advanced techniques (Budgets III-A and IV-A) increased relatively less than labor costs with standard techniques, they were not small enough to totally offset the larger fixed costs associated with the advanced techniques.

It was concluded that a farmer with 25 acres of apple orchard and a total of 60 acres of bearing fruit could not profitably adopt the advanced production techniques including the mechanical harvester if he operated the harvester only on his own acreage. The combination of reduced apple prices for mechanical harvesting and high fixed costs per acre due to depreciation and interest charges gave lower net revenue per acre after adopting the advanced production techniques.

Budgeting results for standard production techniques (Budgets V-A and VI-A) and advanced production techniques (Budgets VII-A and VIII-A) for 70 acres of apple orchard gave results similar to those obtained earlier with 25 acres of apples. Net revenue was lower at both $1.50 and $2.00 wage levels with the package of advanced techniques which include mechanical harvesting. At the $1.50 basic wage level, the difference in net revenue was $24.03 per acre less for advanced techniques (Budget VIII-A) which include mechanical harvesting than for hand harvesting (Budget VI-A).

Increasing the regular wage to $2.00 per hour decreased the difference in net return to $4.17 per acre less for advanced techniques. Even though the advanced production techniques had much lower labor costs, they were slightly less profitable than standard production techniques after allocating one half of the depreciation and interest cost of the mechanical harvester to other fruits on the farm. Given this narrow difference in net revenue and the relative ease of managing a crew of four workers with the mechanical harvester in contrast to obtaining and managing a crew of thirty harvest workers, many farmers would find the mechanical harvester an acceptable alternative.

To be profitable, advanced production techniques which include the mechanical apple harvester must have lower fixed costs per acre. Fixed costs per acre can be reduced in one or more of the following ways: (1) expansion of the apple acreage on the farm; (2) perform custom harvesting for other apple growers; and (3) using the mechanical harvester for other crops such as tart cherries, sweet cherries, and plums.

Of the three alternatives, the adaptation of other crops on the same farm appears to be the most promising. Tart cherries and plums are already being mechanically harvested with machines that cost approximately one-half the price of the apple harvester. While the apple harvester may be "overengineered" for the requirements of cherry harvesting, it has been used successfully for harvesting cherries on a limited basis.

Expanding apple acreage on the farm would require several years before the trees were of bearing age. This would also require additional capital investment which might limit the ability of the grower to invest in a mechanical harvester. Custom harvesting apples for other growers in the immediate area presents the problem of harvest timing. The simultaneous ripening of the owner's crop and that of surrounding growers would limit the time available to the owner for custom harvesting after harvesting his own crop.

CHAPTER VI

TART CHERRY ENTERPRISE ADJUSTMENT POSSIBILITIES

The tart cherry production function analysis of Chapter IV indicated there was substantial potential for substituting machinery use for hired labor in the production process. This was true in the enterprise function (Model I-C) and harvesting function (Model VII-C). In each of these functions, the least cost combination of machinery use and hired labor for producing tart cherries indicated movement along the isoquant from the observed mean combinations of machinery use and hired labor to a combination of more machinery use and less hired labor to perform the operations in tart cherry production.

In order to illustrate the potential for adjustment in tart cherry production, two basic partial budgets for tart cherry production are presented. Production techniques that are approximately the same as those used in tart cherry production on the majority of fruit farms in Michigan were assumed for the standard enterprise budget (Budget I-C). The advanced enterprise budget (Budget II-C) assumes the use of labor saving production techniques which are available to a limited extent to to cherry farmers at the present time. All of these labor saving techniques are not usually found in combination on the same farm at the present time, however.

These two budgets illustrate the range of adjustment possibilities that growers will face by 1969-70. The impact of increasing labor costs on production costs in each budget is examined.

The basic farm situation assumed for the two budgets is the same. The farm has 60 acres of bearing fruit, 35 of which are tart cherries. This is thought to be a representative farm for study. Hill found an average total of 59 acres of fruit (bearing and nonbearing) in an area sample of 85 farms in 1966. Seventy-three percent of the farms had cherry orchards (tart and sweet) with an average of 33.4 acres per farm.[1]

Eighty-seven percent of the Large Farm sample farms had cherry orchards (tart and sweet) with an average size of 47.32 acres (82 percent bearing). These farms had an average total acreage of 140 acres of fruit trees.

It was decided that a representative farm with 60 acres of bearing fruit and 35 acres of tart cherries would be examined. This is a size that is only slightly larger than the observed average acreage of farms in the Area Farm sample in 1966 and should be reached by 1969-70 by many of the farms. If adoption of advanced techniques was found to be profitable on this size of cherry enterprise, it should be profitable on the farms represented by the Large Farm sample since the fixed costs of the equipment used for labor replacement in cherries would be spread over larger cherry acreage. Although the farms in the large farm sample were 230 percent larger in

[1]Hill, Resource Use and Returns on Michigan Fruit Farms, p. 11.

terms of total fruit acreage, they were only 40 percent larger in terms of cherry acreage.

The 25 acres of fruit remaining on the farm is assumed to be composed primarily of apples and one or more other fruits. All machinery which is not specialized to cherry production is budgeted to reflect use in the other fruit enterprises by allocation of fixed costs according to the proportion of the total fruit acreage (58 percent) which is cherry orchard.

The budgets include all of the costs incurred during the production process from pruning through delivery of the fruit to the processor or storage. The production functions of earlier chapters did not include transportation from the field to the processor or storage.

The budgets were developed primarily from the following sources: the data obtained for apple and cherry production functions presented in Chapter IV; earlier published and unpublished work in Michigan by O. F. Buller; data from New York farm account records, and; machinery operating costs from Conner, et. al.[2] The information contained in these sources was supplemented by consultation with professionals working closely with fruit production in Michigan.

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[2]Buller, "Labor Inputs, Crop Costs and Returns for Michigan Tree Fruits," pp. 10-12. Buller, "Profitable Adjustments on Selected Michigan Tree Fruit Farms." Kearl, Cash Crops and Fruits, Costs and Returns from Farm Cost Accounts--43 Farms, 1966, pp. 8-9. Conner, Michigan Farm Management Handbook, pp. 27-28.

Standard Cherry Enterprise Budget I-C

The cherry orchard is assumed to have only bearing trees with an average age of 20 years. The machinery and equipment used in the enterprise is assumed to have a present value of one-half of the new replacement cost unless noted otherwise.

Specification of Production Techniques

Pruning

The pruning operation includes the shaping of the trees by the removal of selected growth from the tree and disposal of the pruned limbs. In this budget the removal from the tree is entirely with hand tools. The larger limbs are piled up for burning while the smaller limbs are chopped up with the rotary mower.

Tillage

Controlling weeds and grass in this budget is accomplished by disking the orchard three times to destroy the weeds and dragging the surface twice to maintain a smooth terrain. After harvest a cover crop of rye or oats is sown to prevent erosion of the soil during the winter months.

Spraying

Insecticide application is by a tractor drawn speed sprayer with auxillary motor and a 500-gallon tank. It is assumed that the farmer sprays a dilute or 2x spray mixture which requires more water per pound of chemical applied per acre than the 4x concentration sprays. This requires more time for repeated filling of the sprayer than the use of a 4x concentration. Seven applications of chemicals were assumed.

Harvesting

The cherries are assumed to be picked entirely by hand at a wage rate of $.90 per lug. The cherries are removed from the field by hand loading the 27 pound lugs onto a truck in the field. For a four ton yield this would be from 300-320 lugs of cherries depending upon whether they were filled completely or not.

Miscellaneous

Fertilization by tractor and spreader accounts for one-third of the miscellaneous category with the remainder of the time used for general orchard maintenance, clean up, and mouse baiting.

Budgeting Results

In Budget I-C the cash wage level is assumed to be $1.50 per hour for hired labor. Social security payments of 4.4 percent and workmen's compensation costs of $4.40 per $100 make the cost to the farmer $1.63 per hour. The piecework payment of $.90 per lug for tart cherry harvesting gives an hourly equivalent wage of $1.50.[3]

The harvesting and pruning operations require large amount of labor, $294.11 and $27.71, respectively, of the total labor expense of $344.23 per acre. The harvest operation accounts for 85 percent of the

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[2]Hervey, Worker Productivity in Sweet and Tart Cherry Harvesting, p. 21.

total labor bill. Nonlabor expenses of $67.69 make the total variable expenses $411.92 per acre. The addition of fixed expenses in the form of depreciation and interest on equipment of $38.06 gives a total production cost of $449.98 per acre. Assuming a price of $.087 per pound of cherries and a four ton yield per acre the gross return is $696.[4] This leaves a net return of $246.02 to land, management, and nonequipment overhead.

Advanced Cherry Enterprise Budget (II-C)

This budget uses the most advanced (labor saving) techniques which will be available to cherry producers by 1970. The use of all of these techniques in one budget produces a large reduction in labor use from the quantity used in Budget I-C.

Specification of the Techniques

Pruning

Pruning is accomplished by the use of a hydraulic boom with a working platform which allows the worker to position himself near the area of the tree to be pruned and use hydraulic power pruners to make the pruning cuts. The pruner operates from the hydraulic system of the tractor. Brush removal is accomplished by burning of large limbs and

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[4]The average price received at the farm level for tart cherries in Michigan during the period 1959-1967 was $.087 per pound. This average price was used for budgeting purposes. Much of the variation in price is the result of fluctuations in total supply due to weather variation. Information on production and prices taken from: Michigan Department of Agriculture, Michigan Agricultural Statistics, (September 1967), p. 16. Michigan Department of Agriculture, Michigan Agricultural Statistics, (July 1969), p. 17.

Table 6.1 Budget for Production of Tart Cherries with Standard Techniques of Production and 4 Ton Per Acre Yield (Budget I-C)[a]

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Pruning				
(1) Hand pruning equipment and chainsaw and ladders	hours	15.00	0.10	1.50
(2) Tractor	hours	1.00	1.00	1.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor-pruning, clear brush	hours	17.00	1.63	27.71
Tillage				
(1) Tractor	hours	5.50	1.00	5.50
(2) Disk 6' - 8'	hours	3.50	0.25	0.87
(3) Drag 8' - 12'	hours	1.50	0.10	0.15
(4) Seed for cover crop	--	--	--	1.50
(5) Fertilizer spreader for seeding	hours	0.50	0.25	0.12
(6) Labor	hours	6.00	1.63	9.78
Spraying				
(1) Sprayer 500 gallon 2x	hours	3.00	2.75	8.25
(2) Tractor	hours	3.00	1.00	3.00
(3) Labor	hours	4.75	1.63	7.74
(4) Spray materials	hours	--	--	28.00
Harvesting				
(1) Hand harvest equipment and ladders	hours	5.00	0.10	0.50
(2) Harvest labor 296 lugs @ $.90/lug	--	--	--	266.40

Table 6.1 (Cont'd.)

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Harvesting (cont'd.)				
(3) Trucking	miles	30.00	0.12	3.60
(4) Harvest loading and hauling	hours	17.00	1.63	27.71
Miscellaneous				
(1) Fertilization, clean up labor	hours	3.00	1.63	4.89
(2) Fertilizer spreader	hours	1.00	0.25	0.25
(3) Fertilizer 400 pounds	pounds	400.00	3.00/100	12.00
(4) Tractor	hours	1.00	1.00	1.00
Total variable expenses				
Labor			344.23	
Nonlabor			67.69	
				411.92
Fixed expenses:				
Depreciation and interest on equipment ($1,332.87 ÷ 35)				38.06
Total expenses				449.98
Total revenue ($.087 per pound)				696.00
Net revenue to land, management and nonequipment overhead				246.02

[a]Sixty acres of bearing orchard with 35 acres of tart cherries.

Table 6.2 Inventory of Equipment Investments with Standard Techniques of Production Assumed in Budget I-C

	New replacement cost	Present value	Total useful life	Annual depre- ciation	Interest @ 6 percent	Interest - depre- ciation	Cost share for cherries[a]	Cost per acre
	(dollars)	(dollars)	(years)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sprayer, 500 gallon	4,000	2,000	10	400	120	520	234.00[b]	6.68
Tractor, 3-4 plow	4,500	2,250	10	450	135	585	339.30	9.69
Tractor, 3-4 plow	4,500	2,250	10	450	135	585	339.30	9.69
Truck, 2-ton	3,500	1,750	15	233	105	338	196.04	5.60
Hand pruning equipment	270	135	10	27	8	35	20.36	0.58
7' rotary mower or brush chopper	600	300	10	60	18	78	45.24	1.29
Disk, 7-8 foot	600	300	10	60	18	78	45.24	1.29
Drag, 9 foot	250	125	10	25	8	33	18.85	0.54
Ladders	450	225	5	90	14	104	60.32	1.72
Picking pails, etc.	75	37	10	8	2	10	9.72	0.28
Fertilizer spreader	325	163	10	33	10	43	24.50	0.70
Total	19,070	9,535				2,409	1,332.87	38.06

[a]Cost share for equipment used in production of other fruits is 58 percent of total of interest plus depreciation unless otherwise noted.

[b]Due to fewer spray applications in cherries than apples which make up bulk of remaining acreage, depreciation and interest assumed to be .7 as large per acre of cherries as other fruits.

shredding remaining limbs with a brush chopper. The tree hedger is not used in this advanced pruning operation because there is no conclusive evidence that there is a real savings of labor with the hedger. The tendency of undesirable growth patterns to develop after several years of hedging may require enough hand pruning to offset the labor system in the earlier years.

Tillage

Tillage practices in this budget are designed with a sod maintenance program rather than clean tillage as with disking and dragging. Sod maintenance provides a uniform surface for harvester operation which will provide firm support during wet weather conditions. Weed spraying to control weeds and grasses is applied in the spring when grass and weed growth is approximately six inches high with a boom sprayer. This is supplemented with mowing for complete weed control.

Spraying

The spraying operation consists of insecticide application with a 500 gallon speed sprayer. A 4x spray concentration is used which allows more spray material to be applied per gallon of water than with a dilute or 2x concentration. This allows coverage of larger acreages between stops for water filling.

Harvesting

A mechanical cherry shaker is used for cherry harvesting. The cherry shaker consists of two self-propelled units (halves) which are positioned on opposite sides of the tree to form a complete catching surface around the tree. Each half has an auxillary engine to provide power for locomotion and operation of a hydraulic system. A hydraulic shaker boom attached to each half-frame is used for limb shaking to remove the ripened fruit. One half-frame has a conveyor that empties the harvested fruit into a water filled tank for cooling. The harvested fruit must be kept at temperatures below 68°F. to avoid scald damage to the harvested cherries. These bulk tanks are taken from the field by forklift to a cooling platform where cool well water is circulated through the tanks to reduce the temperature of the cherries. The tanks are loaded on a truck by forklift for transportation to the processor.

A crew of five persons is required to operate the mechanical harvester and forklifts with one additional worker required for hauling harvested cherries to the processor. The rate of operation is approximately 20 trees per hour or 5 hours per acre. This results in considerably less labor use than the hand harvest method as indicated in Budget II-C.

Miscellaneous

Fertilization is assumed to be done on a custom service basis. The remaining items in the miscellaneous category are clean-up and miscellaneous operations such as mouse baiting.

Budgeting Results

In Budget II-C the cash wage level is assumed to be $1.50 per hour for hired labor with the exception of the supervisor of the mechanical harvesting crew who receives $2.50 per hour. Successful operation of the harvester requires that at least one member of the crew be qualified to make minor repairs and adjustments on the harvester. Persons possessing such skills cannot usually be hired for $1.50 per hour.

The reduction in expenditures on labor in harvesting and pruning operations from those in Budget I-C is rather large (Table 6.3). Harvesting and pruning operations require $70.65 labor expenditures as contrasted with $321.82 for Budget I-C. The $54.35 spent on harvest labor in Budget II-C is approximately one-fifth as large as the $294.11 spent in Budget II-C. Part of the large savings in labor expenditure is offset by increased machinery depreciation and interest costs. Fixed costs are $128.41 per acre in Budget II-C and $38.06 per acre in Budget I-C. This increase in fixed costs is not enough to offset the large decrease in labor expenditures, however, Total production costs are $311.46 in Budget II-C. Assuming a five percent loss in total revenue due to field loss of the harvester and possible reduction in grade, we have total revenue of $661.20 with mechanical harvesting. This leaves a net return of $349.74 for Budget II-C.

Effect of Increasing Wage Levels

With the assumption of $1.50 wage levels in 1970 for labor used in tart cherry production, the net revenue for the advanced production practices

Table 6.3 Budget for Production of Tart Cherries with Advanced Techniques of Production and 4 Ton Per Acre Yield (Budget II-C)[a]

Item	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Pruning				
(1) Wishbasket power pruner	hours	7.00	0.55	3.85
(2) Tractor 3-plow	hours	8.00	1.00	8.00
(3) 7' rotary mower	hours	1.00	0.45	0.45
(4) Labor--pruning, clear brush	hours	10.00	1.63	16.30
Tillage				
(1) Sprayer (6' weed)	hours	0.50	0.30	0.15
(2) 7' rotary mower	hours	1.50	0.45	0.67
(3) Tractor 3-plow	hours	2:00	1.00	2.00
(4) Labor	hours	2.00	1.63	3.26
(5) Spray materials 1 lb. paraquat 2 lbs. simazine	pounds	3.00	--	9.74
Spraying				
(1) Sprayer 500 gallon 4x	hours	2.50	2.75	6.88
(2) Tractor 3-plow	hours	2.50	1.00	2.50
(3) Labor	hours	4.50	1.63	7.33
(4) Spray materials 7 applications	--	--	--	28.00
Harvesting				
(1) Self-propelled cherry shaker (both halves)	hours	5.00	1.50	7.50
(2) Tractor and forklift ($1,000 fork)	hours	5.00	1.20	6.00

Table 6.3 (Cont'd.)

	Requirements Per Acre			
	Unit	Quantity	Price (dollars)	Amount (dollars)
Variable expenses				
Harvesting (cont'd.)				
(3) Tractor and fork ($250 fork)	hours	5.00	1.03	5.15
(4) Bulk tanks (3)	hours	5.00	0.05	0.25
(5) Labor--4-man crew	hours	20.00	1.63	32.60
supervisor	hours	5.00	2.72	13.60
(6) Trucking	miles	30.00	0.12	3.60
(7) Labor--hauling	hours	5.00	1.63	8.15
(8) Pump, well, cooling platform	ton of cherries	4.00	.10/ton	0.40
Miscellaneous				
(1) Fertilization, clean up labor	hours	2.50	1.63	4.07
(2) Fertilization, bulk speader @ $3/ton	--	--	--	0.60
(3) Fertilizer, 400 pounds	pounds	400.00	3.00/100	12.00
Total variable expenses				
Labor expenses			85.31	
Other expenses			97.74	
				183.05
Fixed expenses				
Depreciation and interest on equipment ($1,494.77 ÷ 35)				128.41
Total expenses				311.46
Total revenue				661.20
Net revenue to land, management and nonequipment overhead				349.74

[a]Sixty acres of bearing orchard with 35 acres of tart cherries.

Table 6.4 Inventory of Equipment Investments with Advanced Production Techniques of Budget II-C

Equipment	New replacement cost (dollars)	Present value (dollars)	Total useful life (years)	Annual depreciation (dollars)	Interest @ 6 percent (dollars)	Interest + depreciation (dollars)	Cost share for cherries[a] (dollars)	Cost per acre (dollars)
Sprayer, 500 gallon, 4x concentration	4,000	2,000	10	400	120	520	234.00[b]	6.69
Tractor, 3-4 plow	4,500	2,250	10	450	135	585	339.30	9.69
Tractor, 3-4 plow	4,500	2,250	10	450	135	585	339.30	9.69
Forklift	1,000	500	10	100	30	130	75.40	2.15
Self-propelled harvester	12,472	6,236	6	2,079	374	2,453	2,453.16	70.09
30 bulk tanks	1,650	825	10	165	50	215	215.00	6.14
3-point forklift	250	125	10	25	8	33	18.85	0.54
Wishbasket pruner	1,833	916	8	229	55	284	164.70	4.71
Weed sprayer	250	125	10	25	8	33	23.78	0.68
7' rotary mower	600	300	10	60	18	78	45.24	1.29
Truck 2-ton	3,500	1,750	15	233	105	338	196.04	5.60
Pump, well, colling platform	3,000	1,500	10	300	90	390	390.00	11.14
Total	37,555	18,777				5,644	4,494.77	128.41

[a]Cost share for equipment used in production of other fruits is 58 percent of total interest plus depreciation unless otherwise noted.

[b]Due to fewer spray applications in cherries than apples which make up bulk of remaining acreage, depreciation and interest assumed to be .7 as large per acre of cherries as other fruits.

(Budget II-C) was $103.72 per acre greater than net revenue from Budget I-C for the same production per acre (Table 6.5). This is a difference of $3,630.70 net income on the 35 acres of tart cherries, primarily due to labor replacement in pruning and harvesting operations.

If there is general economic prosperity in the nation accompanied by low levels of unemployment, the wage level could easily have to be as high as $2.00 to attract workers to perform the tasks included in the production activities. This would result in an even greater difference in net revenue for the two budgets under consideration. Labor costs would increase by $115.07 per acre with standard production techniques (Table 6.5). With advanced production techniques labor costs increase by $26.91. This gives a net revenue difference of $191.28 per acre in favor of the advanced production techniques of Budget II-C. This is a difference of $6,695 net income on the 35 acres of tart cherries.

It becomes apparent that as the wage level increases, the difference in net income from the two basic budgets increases for a given level of production. This is due to the large use of labor in pruning and harvesting operations in Budget I-C relative to Budget II-C.

In light of the recent experience with rising wage levels for workers on Michigan farms, it appears that the incentive for adoption of the advanced production techniques in the form of mechanical pruners and mechanical cherry harvesters will be even greater in the near future. Other factors, such as the relative ease of acquiring and managing a crew of five workers to operate a cherry harvester as opposed to a crew of thirty workers for

Table 6.5 Costs and Returns Per Acre From Tart Cherry Production with Standard and Advanced Practices for Two Alternative Wage Levels[a]

Item	$1.50 Wage Level Standard Production Techniques Budget I-C	$1.50 Wage Level Advanced Production Techniques Budget II-C	$2.00 Wage Level Standard Production Techniques Budget I-C	$2.00 Wage Level Advanced Production Techniques Budget II-C
	(dollars)	(dollars)	(dollars)	(dollars)
Variable expenses				
Labor	344.23	85.31	459.30	112.22
Nonlabor	67.69	97.74	67.69	97.74
Total	411.92	183.05	526.99	209.96
Fixed expenses				
Depreciation and interest	38.06	128.41	38.06	128.41
Total expenses:	449.98	311.46	565.05	338.37
Total revenue	696.00	661.20	696.00	661.20
Net revenue:	246.02	349.74	130.95	322.83

[a]Yield of 4 tons per acre assumed on 35 acre orchard.

hand harvest, have not been taken into account in the discussion. These considerations make the advanced techniques of Budget II-C appealing as an aid in labor management in addition to lowering production costs.

Effect of Alternative Yields

Total production of tart cherries in Michigan is quite variable on a year-to-year basis. Tart cherries are more susceptible to late spring freezes than other major crops such as apples. Production in Michigan during the period 1959-67 varied from a low of 37,000 tons in 1963 to a high of 190,000 tons in 1964 on essentially the same total acreage of trees. The individual producer experiences variability in year-to-year production of similar magnitude.

In Table 6.6 the costs of production per pound with alternative yields per acre are examined. The cost per pound is lower with advanced techniques in all yield-wage combinations except the two ton yield--$1.50 wage combination. At the $2.00 wage level, costs per pound with advanced techniques are lower for all yield levels considered. The differential in cost per pound increases with yield per acre primarily because the harvesting costs per acre are relatively fixed with respect to yield with mechanical harvesting, while harvest cost per acre vary almost proportionately with yield with hand harvesting. It appears that advanced techniques effectively reduce the production cost per pound over the yield and wage level combinations that most farmers would anticipate.

Table 6.6 Cost per Pound for Producing Cherries on 35 Acres of Bearing Cherry Orchard with Alternative Techniques with $1.50 and $2.00 Wage Levels for Different Yields per Acre

Production Techniques	Yield Per Acre 2 Tons	3 Tons	4 Tons	5 Tons
	¢/lb.	¢/lb.	¢/lb.	¢/lb.
$1.50 Wage Level				
Standard Production Techniques of Budget I-C	7.5	6.3	5.6	5.2
Advanced Production Techniques of Budget II-C	7.7	5.2	3.9	3.1
$2.00 Wage Level				
Standard Production Techniques of Budget I-C	9.2	7.8	7.1	6.6
Advanced Production Techniques of Budget II-C	8.4	5.6	4.2	3.4

Potential Labor Adjustments

The budget analysis indicated that using a mechanical cherry harvester increased net revenue per acre from tart cherry production for the farm firm. A comparison of the labor requirements to achieve the same harvest rate with hand and mechanical harvesting is made with a view toward the potential labor adjustment that could result from adaption of mechanical harvesting.

Timeliness of harvest is very important in tart cherry production. Since cherries reach maturity in hot summer months, it is essential to harvest them before the quality deteriorates or some are lost due to a windstorm. In the budget analysis, it was assumed that the mechanical harvester would harvest 1,600 pounds of tart cherries per hour (approximately one fifth acre per hour) with a crew of five workers in an orchard with a four ton per acre yield. It would require 35 to 40 workers to achieve the same harvest rate per hour with hand harvesting. This assumes an average picker productivity of 1.65 lugs per hour, which was observed in picker productivity studies in 1966. The labor management problem is reduced significantly with one seventh as large work crew to recruit and supervise with mechanical harvesting. Adoption of the mechanical harvester reduces the dependency of the farmer upon large amounts of seasonal labor and makes it easier to perform most of the operations in cherry production with a crew of regular hired workers.

Statistics on labor use in cherry harvesting (combined tart and sweet cherries) of the Michigan Employment Security Commission indicate an average of 36,390 workers were employed at the peak cherry harvesting period (July 31) during the years from 1964 to 1967. Tart cherries average approximately four fifths of total cherry production. "Interstate" workers constituted 69 percent of the seasonal work force employed in cherry harvesting.[5] With the large reduction in labor requirements accompanying mechanical harvesting, adoption of mechanical harvesting by large numbers of growers would reduce the demand for seasonal labor in cherry harvesting. This reduction in seasonal labor requirements would undoubtedly reduce the employment of "interstate" workers, which would also affect the supply of seasonal workers available for other fruit crops. The harvest of cherries has historically required the largest labor force of the fruit crops and with strawberries has drawn workers to the area who would subsequently harvest other fruits.

Summary

Earlier tart cherry enterprise production function analysis (Chapter IV) indicated that adjustments in the combinations of machinery and hired labor inputs should be made in order to reach the least cost combination of resources for cherry production. Partial budgeting was used to evaluate the production costs and returns from two alternative sets of production techniques. The standard cherry enterprise budget

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[5]Average of employment reported for that period for the years 1964 through 1967 as found in the annual publication of the Michigan Employment Security Commission, Michigan Farm Labor Report - Post Season 1964 (and subsequent years of 1965, 1966 and 1967).

employed the production techniques commonly used in tart cherry production on Michigan farms. The advanced cherry enterprise budget assumed the most advanced techniques available by 1969-1970.

Production costs were determined for a basic farm situation of 60 acres of bearing orchard, 35 of which was tart cherries. Two basic wage levels of $1.50 and $2.00 per hour were assumed to evaluate the impact of higher wage levels on the relative profitability of the two budgets.

The net returns per acre were greater for the advanced techniques (Budget II-C at both wage levels. As the wage level increased, the low level of labor use with the advanced techniques increased the difference in net revenue from $103.72 per acre at the $1.50 wage level to $191.88 per acre at the $2.00 wage level.

There is an interesting contrast in the relative profitability of mechanical harvesting as budgeted for apples and tart cherries. Mechanical harvesting of tart cherries with a mechanical harvester which costs approximately $13,000 is profitable in the farm organization examined. If the price were $15,000 it would still be profitable to harvest tart cherries mechanically. Therefore, allocation of one-half of the investment cost of a $30,000 multicrop harvester to the cherry enterprise would give a profitable cherry operation. It would also increase the relative profitability of the apple budgets examined earilier which included a mechanical harvester by lowering the fixed costs per acre.

In conclusion, it appears that adoption of advanced production techniques, foremost of which is the mechanical cherry harvester, provides the grower with a higher net revenue per acre which increases relative to that from standard production techniques as wage levels rise.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The primary objective of this study was to evaluate the productivity of resources at the enterprise level for apple and tart cherry production on Michigan fruit farms. The analysis included reporting the use of labor and equipment in the operations performed on these two crops with production functions fitted at the enterprise level. In addition, the impact of adopting advanced technologies upon these enterprises was examined.

More specifically the objectives were:

1. To report the observed use of labor and machinery in the production of apples and tart cherries with analysis of the differences observed between farms in the use of machinery and labor.
2. To develop production functions to statistically explain the production relationships observed for apples and tart cherries, with emphasis on the marginal value products and marginal rates of substitution for the factors of production.

3. To evaluate the impact of adopting new production technologies on the use of labor and capital in these enterprises through the use of partial budgeting techniques.

The basic data was obtained from a sample of 258 Michigan fruit farms which yielded 77 apple and 68 tart cherry enterprise observations.

Analysis of apple production techniques indicated that apple producers were adopting successfully tested advanced techniques of production. The pruning, tillage, and spraying operations were usually mechanized as much as was practical. The largest source of labor use, harvesting, had not been mechanized to any large extent. Only the fruit handling stage had been mechanized since there was not an operational harvester at the time of the survey.

Analysis of tart cherry production techniques indicated that cherry producers were adopting labor saving techniques to a limited extent in all operations. The potential for labor reduction was greater in tart cherries due to the availability of an operational mechanical harvester. Seventeen of the 68 farmers were using mechanical harvesters in 1966. Among those who were still using hand harvesting, the use of labor saving fruit handling techniques was very low. This indicated a failure to adopt an intermediate labor saving device on the part of many growers.

Resource productivity in apple production was examined through production function analysis. Equations were fitted at the enterprise level and for two major operations within the enterprise, i.e., pruning and harvesting.

The enterprise and harvest operation production functions were fitted to a Cobb-Douglas function with total sales as the dependent variable. The pruning operation was fitted with the total number of trees upon which the operation was performed as the dependent variable.

Among the independent variables that were used, hours of machinery use, number of trees, and hired labor were found to have the greatest explanatory power and were significant in every production function in which they were included. The independent variable, family labor, was significant in only one equation. Expenditures for custom operations were not significant in explaining variation in production in any of the equations in which they were included.

At the enterprise level and for the harvesting operation there was no indication of other than constant returns to scale in apple production. The pruning production function had a sum of elasticities which was significantly less than one.

Examination of isoquant relationships between hired labor and machinery use indicated substantial increases in machinery use accompanied by decreases in hired labor use in order to reach the least cost combination of the two resources for the enterprise, harvest, and pruning operation production functions.

As with apples, resource productivity in cherry production was examined through production function analysis. The enterprise and harvest operation production functions were fitted with total sales as the dependent variable. The pruning operation was fitted with the total number of trees as the dependent variable.

Among the independent variables that were used, hours of machinery use, number of trees, and hired labor were found to have the greatest explanatory power and were significant in every production function in which they were included. Neither family labor nor expenditures for custom operations was significant in any equation.

The enterprise function and the harvesting function had sums of elasticities which were not significantly different from one indicating constant returns to scale. The pruning function had a sum of elasticities that was significantly less than one.

Examination of isoquant relationships between hired labor and machinery use indicated substantial increases in machinery use accompanied by decreases in hired labor use in order to reach the least cost combination of the two resources for the enterprise and harvest operation functions. In the pruning operation there was no change indicated from the observed mean combination of machinery use and hired labor.

There was no evidence of other than constant returns to size at the enterprise level for apples and tart cherries. Hill found little evidence of increasing returns to size for fruit farms at the total farm level. One subset of 21 farms that received more than fifty percent of their gross revenue from cherry production had increasing returns to size.[1] In all other cases studied by Hill there were either constant or decreasing returns to size. The evidence in these two studies gives little support to evidence of economic incentives for greatly enlarged fruit farms under the conditions prevailing at the time of this study.

Partial budgeting was used to evaluate the production costs and returns from two basic sets of apple enterprise budgets. The standard apple enterprise budgets employed the production techniques commonly used in apple production on Michigan farms. The advanced apple enterprise budgets employed the most advanced techniques available by 1969-70.

Production costs were determined for two basic wage levels of $1.50 and $2.00 per hour, and two orchard sizes. With the 25-acre apple orchard, budgets with standard production techniques plus mechanical pruning gave higher net returns per acre at both wage levels. Adoption of the mechanical pruner was found to increase net returns per acre above those of the standard technique budget. The larger fixed costs and lower product price associated with the mechanical harvester made the advanced techniques budget less profitable than the standard techniques for the 25-acre orchard.

It was concluded that a farmer with 25 acres of apple orchard could not profitably adopt the advanced production techniques including the mechanical harvester if he operated the harvester only on 25 acres

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[1]Hill, Resource Use and Returns on Michigan Fruit Farms, p. 108.

of orchard.

For the 70-acre orchard, results similar to those for the 25-acre orchard were obtained. Net revenue was lower at both $1.50 and $2.00 wage levels for advanced harvesting techniques although the difference was only $4.17 per acre less with the advanced techniques budget. Even though the advanced production techniques had much lower labor costs, they were slightly less profitable than standard production techniques due to the large fixed cost of the mechanical harvester. This relatively large fixed cost was reduced to a level that made the net revenue from the mechanical harvesting budgets nearly as large as net revenue from budgets without mechanical harvesting by assuming that the harvester would be used for multiple fruit harvests and allocating only one half of the depreciation and interest cost to apples.

It was concluded that for many farmers the adoption of advanced techniques including a mechanical harvester would be profitable if fixed costs per acre were reduced by one or more of the following methods: (1) expansion of the apple acreage on the farm; (2) perform custom harvesting for other apple growers, and; (3) using the mechanical harvester for other crops such as tart cherries, sweet cherries, and plums.

The adoption of advanced techniques has the potential for reducing the quantity of hired labor used on most apple farms. In the harvesting operation there is a potential reduction of harvest labor use by 75 percent on those farms which adopt mechanical harvesting. This would reduce the dependency of apple producers on large amounts of seasonal hired labor.

Hired labor expenditures for harvesting on farms not using mechanical harvesting accounted for 82 percent of the total hired labor bill for apple production on farms surveyed in 1966. Mechanization of apple harvesting by substantial numbers of apple growers would reduce the total demand for seasonal labor at the industry (apple farms collectively) level.

Partial budgeting was used to evaluate the production costs and returns from two alternative sets of production techniques for tart cherries. The standard cherry enterprise budget employed the production techniques commonly used in tart cherry production on Michigan farms. The advanced cherry enterprise budget assumed the most advanced techniques available by 1969-70.

Production costs were determined for a basic farm situation of 60 acres of bearing orchard, 35 of which was tart cherries. Two basic wage levels of $1.50 and $2.00 per hour were assumed to evaluate the impact of higher wage levels on the relative profitability of the two budgets.

The net returns per acre were greater for the advanced techniques of production at both wage levels. As wage levels increased, the difference in net revenue from the standard and advanced techniques increased due to the relatively low level of labor use with advanced techniques. This reduction in labor use was primarily due to using a mechanical cherry harvester.

It was concluded that a farmer with 35 acres or more of tart cherries could afford to adopt the advanced techniques of production for cherries at a wage as low as $1.50 per hour and a yield of three tons per acre. As wages or yields per acre increased the advanced techniques were relatively more profitable than hand harvesting.

The relatively large percentage of total labor costs associated with the cherry harvesting operation was discussed in Chapter II. Since the labor requirements per acre were approximately one-seventh as large as for advanced techniques which included mechanical harvesting as they were with hand harvesting, there is potential for substantial reduction in labor used for tart cherry harvesting. Adoption of mechanical harvesting by large numbers of tart cherry growers will reduce the demand for the large quantities of seasonal labor that have been used by tart cherry producers for many years.

On the basis of production function and partial budgeting analysis completed in this study, it appears that substantial reductions in the quantity of labor used per unit of product in apple and tart cherry production will be forthcoming. Increases in labor costs will accelerate these adjustments by making labor saving technologies more profitable.

Reduction of labor use in the harvesting operations of apple and tart cherry production appeared to have the greatest potential. Given the large quantities of labor that have traditionally been used in apple and tart cherry harvesting, a sharp reduction in labor use in these fruits will affect the over-all summer employment opportunities available in

Michigan. The attraction of nearly continuous employment in a small geographic area for large numbers of migrant laborers from June to October will be reduced. Mechanization of tart cherry harvesting will reduce the employment available in July and August, while mechanization of apple harvesting will reduce employment available in September and October.

Reduction of employment prospects in the later summer months may limit the ability of strawberry growers to attract workers to Michigan for strawberry harvesting in June. Harvest labor use in strawberries has been second only to cherry harvesting in recent years. Other Michigan fruit crops are also dependent upon large amounts of seasonal labor and would be seriously affected by a disruption of the traditional pattern of labor use in Michigan. Assessing the total impact of future technology adoption is beyond the scope of this study. It is clear, however, that there is a large potential for labor adjustments in apple and tart cherry production. These adjustments will affect growers of other fruits in Michigan through a disruption of the traditional seasonal pattern of employment in fruit harvesting. This may bring increased pressure for labor saving mechanization in the production of those fruits if labor becomes more expensive and difficult to obtain.

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APPENDICES

APPENDIX A

MACHINERY INVENTORY VALUATION

MACHINERY INVENTORY VALUATION

Each farmer was asked to give an inventory of the equipment used in fruit production on his farm. Information included the specification of the size and model year of each item. The present value was subsequently determined for each piece of equipment.

The equipment on each farm was evaluated in the following manner:[1]

1. New and used tractor prices for 1966 were obtained from the Fall 1966 Tractor and Farm Equipment Guide of the National Farm and Power Equipment Dealers Association.

2. New and used truck prices were obtained for the October 1966 NADA Official Used Car Guide for those years listed. For earlier models not included in the Guide, a depreciated 1966 new price was used as in 4. below.

3. Certain pieces of fruit equipment were used extensively in localized areas but did not have a national market. Thus, no used equipment prices were available in published form.

[1]This explanation is reproduced essentially as it appears in Hill, Resource Use and Returns on Michigan Fruit Farms, p. 71. Quotations are not used since the machinery valuation scheme was developed by the author in conjunction with Roger P. Hill.

Interveiws with farm equipment dealers in the fruit growing area were used to obtain estimates.[2]

4. For certain specialized equipment used on fruit farms there was not an adequate used-equipment market for determining used equipment prices. In cases of an inadequate used equipment, a 1966 value was estimated using the double declining balance depreciation method. It was necessary to assume that the 1966 value of equipment purchased in the year 1966-n was equivalent to the depreciated value of a new 1966 item of comparable equipment in the n^{th} year after purchase.[3]

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[2]The author interviewed twelve farm equipment dealers in Southwestern Michigan to obtain the necessary prices. These dealers were all in areas with large concentrations of fruit growers. The dealers were asked to estimate the trade-in value of various items of machinery and equipment, representing essentially the on-farm value of the equipment. The dealers provided estimates for major items of equipment on a model year basis or, at most, on a three-year interval basis. They also indicated the age at which annual depreciation became negligible for many items. From the information provided by dealers, it was possible to construct a series of prices indicating the present value of major items of machinery and equipment. Some of the major items estimated in this manner included orchard disks and drags, orchard sprayers, fork lifts, tree hoes, mowers and transplanters.

[3]Items included in this category were special harvesting equipment, primarily cherry harvesters, irrigation equipment, pruning aids and bulk tanks. The double declining balance depreciation method was used in an effort to more closely approximate the salvage value of equipment. The double declining balance method works as follows: If the productive life of an item of equipment is estimated at five years, the normal straight-line depreciation would be 20 percent per year; with the DDB method the first-year depreciation is 40 percent of the new price, the second-year depreciation is 40 percent of the remaining balance, etc., until the salvage value is reached. This type depreciation allows a much faster write-off in the earlier years. This method of depreciation appeared to most closely approximate salvage value.

The equipment and number of hours it was used in each operation was listed for the apple or cherry enterprise. The hours of use were multiplied by the current value of the machinery divided by $1,000 in order to obtain the hours use of $1,000 value of equipment. This gave all of the equipment inputs on a common denominator, which facilitated aggregation of machinery inputs within the enterprise. This overcame the obstacle of adding three hours of tractor use with three hours of sprayer use, etc.

APPENDIX B

ELASTICITIES AND RELATED STATISTICS FOR APPLE AND TART CHERRY PRODUCTION FUNCTIONS

Appendix Table B.1 Elasticities and Related Statistics for Three Apple Production Functions

Model	Value of constant	Elasticities: Number of trees	Elasticities: Hours of $1,000 value of equipment	Elasticities: Custom operations	Elasticities: Family labor	Elasticities: Hired labor	Sum of elasticities	Coefficient of multiple determination	Standard error of estimate	Number of observations
Model I-A	1.241	*** .5127 (.0784)	*** .2235 (.0812)	-.0115 (.0369)	.0260 (.0216)	*** .1881 (.0502)	0.94	.87	.1545	77
Model V-A	1.425	*** .6423 (.0623)	*** .1343 (.0533)		-.0046 (.0183)	*** .1443 (.0404)	0.92	.86	.1617	77
Model VII-A	2.167		*** .2657 (.0764)		.0097 (.0390)	*** .1351 (.0377)	0.41	.38	.3544	76

Appendix Table B.2 Elasticities and Related Stastistics for Two Apple Production Functions

Model	Value of constant	Elasticities: Hours of $1,000 value of equipment per 100 trees	Custom operations per 100 trees	Family labor per 100 trees	Hired labor per 100 trees	Sum of elasticities	Coefficient of multiple determination	Standard error of estimate	Number of observations
Model III-A	2.070	.2241*** (.0727)	.1016 (.0900)	.0768** (.0339)	.2077*** (.0500)	0.61	.43	.1497	77
Model VI-A	2.315	.0819* (.0506)		.0629 (.0562)	.2634*** (.0477)	0.41	.46	.1446	77

Appendix Table B.3 Elasticities and Related Statistics for Three Cherry Production Functions

Model	Value of constant	Elasticities: Number of trees	Elasticities: Hours of $1,000 value of equipment	Elasticities: Custom operations	Elasticities: Family labor	Elasticities: Hired labor	Sum of elasticities	Coefficient of multiple determination	Standard error of estimate	Number of observations
Model I-C	1.384	.4033*** (.1085)	.2276** (.1028)	.0362 (.0384)	-.0141 (.0372)	.2102*** (.0515)	0.89	.70	.2389	68
Model VII-C	1.275	.5385*** (.1117)	.1167* (.0637)	.0333 (.0374)	-.0122 (.0333)	.2157*** (.0508)	0.89	.73	.2265	68
Model IX-C	2.406		.3326*** (.0777)		.0495 (.0540)	.0647 (.0433)	0.45	.36	.3012	63

Appendix Table B.4 Elasticities and Related Statistics for Two Cherry Production Functions

		Elasticities							
Model	Value of constant	Hours of $1,000 value of equipment per 100 trees	Custom operations per 100 trees	Family labor per 100 trees	Hired labor per 100 trees	Sum of elasticities	Coefficient of multiple determination	Standard error of estimate	Number of observations
Model IV-C	1.620	.2399***	.0907	.0437	.3301***	0.70	.42	.2297	68
		(.0998)	(.0721)	(.0552)	(.0616)				
Model VIII-C	1.873	.1081*	.0716	.0540	.3377***	0.57	.34	.2147	68
		(.0618)	(.0694)	(.0622)	(.0614)				

Appendix Table B.5 Simple Correlations Among Independent Variables for Three Apple Production Functions

Model and Variables Included	Independent Variables: Number of Trees	Hours of $1,000 Value of Equipment	Custom Operations	Family Labor	Hired Labor
Model I-A					
Number of Trees	1.00				
Hours of $1,000 Value of Equipment	0.76	1.00			
Custom Operations	0.08	-0.09	1.00		
Family Labor	-0.05	0.12	-0.06	1.00	
Hired Labor	0.79	0.72	0.01	-0.01	1.00
Model V-A					
Number of Trees	1.00				
Hours of $1,000 Value of Equipment	0.57	1.00			
Family Labor	-0.10	0.18	X	1.00	
Hired Labor	0.67	0.55	X	-0.01	1.00
Model VII-A					
Hours of $1,000 Value of Equipment	X	1.00			
Family Labor	X	0.11	X	1.00	
Hired Labor	X	0.37	X	-0.28	1.00

Appendix Table B.6 Simple Correlations Among Independent Variables for Two Apple Production Functions

Model and Variables Included	Independent Variables			
	Hours of $1,000 Value of Equipment per 100 Trees	Custom Operations per 100 Trees	Family Labor per 100 Trees	Hired Labor per 100 Trees
Model III-A				
Hours of $1,000 Value of Equipment per 100 Trees	1.00			
Custom Operations per 100 Trees	-0.06	1.00		
Family Labor per 100 Trees	0.49	-0.17	1.00	
Hired Labor per 100 Trees	0.20	0.02	-0.08	1.00
Model IV-A				
Hours of $1,000 Value of Equipment per 100 Trees	1.00			
Family Labor per 100 Trees	0.58	X	1.00	
Hired Labor per 100 Trees	0.38	X	0.38	1.00

Appendix Table B.7 Simple Correlations Among Independent Variables for Three Cherry Production Functions

Model and Variables Included	Independent Variables: Number of Trees	Hours of $1,000 Value of Equipment	Custom Operations	Family Labor	Hired Labor
Model I-C					
Number of Trees	1.00				
Hours of $1,000 Value of Equipment	0.72	1.00			
Custom Operations	-0.01	-0.16	1.00		
Family Labor	0.07	0.11	-0.09	1.00	
Hired Labor	0.53	0.50	-0.21	-0.11	1.00
Model VII-C					
Number of Trees	1.00				
Hours of $1,000 Value of Equipment	0.61	1.00			
Custom Operations	-0.02	-0.18	1.00		
Family Labor	-0.06	0.22	-0.11	1.00	
Hired Labor	0.58	0.31	0.19	-0.13	1.00
Model IX-C					
Hours of $1,000 Value of Equipment	X	1.00			
Family Labor	X	0.06	X	1.00	
Hired Labor	X	0.33	X	-0.61	1.00

Appendix Table B.8 Simple Correlations Among Independents for Two Cherry Production Functions

Model and Variables Included	Independent Variables			
	Hours of $1,000 Value of Equipment per 100 Trees	Custom Operations per 100 Trees	Family Labor per 100 Trees	Hired Labor per 100 Trees
Model IV-C				
Hours of $1,000 Value of Equipment	1.00			
Custom Operation per 100 Trees	-0.21	1.00		
Family Labor per 100 Trees	0.32	-0.03	1.00	
Hired Labor per 100 Trees	0.24	-0.23	-0.12	1.00
Model VIII-C				
Hours of $1,000 Value of Equipment per 100 Trees	1.00			
Custom Operations per 100 Trees	-0.21	1.00		
Family Labor per 100 Trees	0.32	-0.03	1.00	
Hired Labor per 100 Trees	0.08	0.22	0.29	1.00

APPENDIX C

DETERMINING MARGINAL COST OF AN HOUR'S USE OF $1,000 VALUE OF EQUIPMENT

DETERMINING MARGINAL COST OF AN HOUR'S USE OF $1,000 VALUE OF EQUIPMENT

Equipment used in the apple and cherry enterprise data was classified into three types on the basis of initial cost and rate of use. Class I was tractors and other similar power sources which have reasonably high initial costs and are used extensively during the year. Class II was equipment that is often used with the tractor or other power source, such as disks, mowers, sprayers, manure loader and fork, etc. These items have intermediate initial costs and are used less extensively during the year than tractors. Class III was composed of hand tools commonly used in orchard operations, such as chain saws, ladders, pruners, and hand picking equipment. These items have low initial costs and are not used extensively during the year.

Of the 281,662 hours of equipment use observed in the apple and cherry enterprise data, 35 percent of the hours were of Class I equipment, 42 percent were of Class II equipment, and 23 percent were of Class III equipment.

It was necessary to develop a weighted marginal cost of an hour's use of $1,000 value of equipment based on the relative costs of each of these three classes of equipment.

Data from Conner, et. al., which was developed to represent equipment costs on Michigan farms were used to develop costs figures for Classes I and II. For example, a 3-4 plow diesel tractor with the following characteristics would have a total cost per hour of $1,000 equipment use of $.75: (1) New price = $5,185, (2) 10-year useful life, (3) 650 hours use annually, (4) total operating cost per hour is $.92, (5) annual ownership cost is $658. Ownership cost per hour of use equals $1.01 $\left(\frac{658 \text{ dollars}}{650 \text{ hours}}\right)$.[2] Total operating plus ownership cost is $1.93 per hour of use. Assuming the average tractor of this type would have a capital value of one-half of its original price we obtain a cost of $.75 per hour use of $1,000 value of equipment, $\left(\$1.93/\text{hr.} \div \frac{\$2,592}{\$1,000}\right)$, for the tractor.

Using the same approach, the cost per hour use of $1,000 value of equipment was developed for four pieces of Class II equipment commonly used on fruit farms: (1) Pull-type sprayer, $3.03 (2) 12-foot tandom disk, $2.80, (3) grain drill, $4.05, and (4) 7-foot mower, $2.78. The average cost of these four pieces of equipment would be $3.17 per hours use of $1,000 value of equipment.

Class III equipment is primarily composed of ladders, hand pruners, chain saws, and picking pails. Assuming ladders are used in both pruning and harvesting, the average new price of this equipment

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[2] L. J. Connor, et. al., Michigan Farm Management Handbook, (Agricultural Economics Report No. 36, East Lansing, Michigan, Department of Agricultural Economics, Michigan State University, 1967) pp. 27-28.

is \$44. For illustration:

Equipment	New Cost
ladder	\$ 25
hand pruner	7
chain saw	160
ladder	25
picking pail	2
Total	\$219
Average	\$ 44

Assuming total ownership plus operating cost would be 10 percent of new cost regardless of annual use, we obtain a cost of \$.03 per hour of use when the equipment is used for 150 hours annually. Using the same procedures used for Classes I and II, we obtain a cost of \$1.36 per hour of use of \$1,000 value of equipment, $\left(\$0.03/\text{hr.} \div \frac{\$22}{\$1,000}\right)$, for Class III equipment.

Weighting the cost of each class by the percentage of the total hours of equipment use that was observed for that class we have:

(\$.75 x .38) - \$3.17 x .42) - (\$1.36 x .23) - \$1.93

per hour use of \$1,000 value of equipment used in the enterprises. It appears that the figure of \$2.00 is a reasonable marginal cost figure for an hour's use of \$1,000 value of equipment.