AN ANALYSIS OF WORKER PRODUCTIVITY IN APPLE PICKING

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

Charles M. Cuskaden

1971

This is to certify that the

thesis entitled

AN ANALYSIS OF WORKER PRODUCTIVITY
IN APPLE PICKING

presented by

Charles M. Cuskaden

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Ag. Econ.

Lester V. Manderscheid
Major professor

Date Feb. 22, 1971

O-7639

ABSTRACT

AN ANALYSIS OF WORKER PRODUCTIVITY
IN APPLE PICKING

By

Charles M. Cuskaden

Three objectives were established for this study. They were to: (1) investigate factors associated with the productivity of workers being paid on a piece-rate system for harvesting apples by hand in Michigan, (2) determine whether the relationship between certain independent variables and the dependent variable (productivity in apple picking) was different for specified subgroups within the total population of workers, and (3) cross-validate the empirical relationships discovered in carrying out objectives one and two using data from two different years--1965 and 1966.

A basic hypothesis of this study was that apple picking labor is not homogeneous. Labor Heterogeneity implies that pickers would be expected to differ in their level of performance (measured in bushels of apples picked per hour) under given conditions. And that pickers with the highest level of performance under one set of conditions would not necessarily have the highest level of performance under some alternative set of conditions. It also implies that pickers having inherently different abilities may perform at the same level if placed in differing working conditions.

The relationship between worker productivity picking apples by hand in Michigan and 23 independent variables representing worker

ABSTRACT

AN ANALYSIS OF WORKER PRODUCTIVITY
IN APPLE PICKING

By

Charles M. Cuskaden

Three objectives were established for this study. They were to: (1) investigate factors associated with the productivity of workers being paid on a piece-rate system for harvesting apples by hand in Michigan, (2) determine whether the relationship between certain independent variables and the dependent variable (productivity in apple picking) was different for specified subgroups within the total population of workers, and (3) cross-validate the empirical relationships discovered in carrying out objectives one and two using data from two different years--1965 and 1966.

A basic hypothesis of this study was that apple picking labor is not homogeneous. Labor Heterogeneity implies that pickers would be expected to differ in their level of performance (measured in bushels of apples picked per hour) under given conditions. And that pickers with the highest level of performance under one set of conditions would not necessarily have the highest level of performance under some alternative set of conditions. It also implies that pickers having inherently different abilities may perform at the same level if placed in differing working conditions.

The relationship between worker productivity picking apples by hand in Michigan and 23 independent variables representing worker

characteristics, management practices, orchard characteristics, and weather conditions was analyzed by ordinary least squares regression analysis. The data consisted of 3,982 worker-day observations on apples being picked by hand in Michigan under the piece-rate system in 1965 and 647 like observations for 1966. Seven regression equations were fitted for each year. Six of these equations contained interaction terms between worker characteristics and other selected independent variables in order to investigate differences in the relationship between these selected variables and apple picking productivity (differential predictability) for subgroups of workers within the total population. The possibility of differential predictability with respect to experience, size, residence, age, sex, and ethnic origin of picking units was investigated.

Residence and experience were the worker characteristics which most consistently differentiated between fast and slow pickers. Residents of states other than Michigan consistently out-performed Michigan residents in picking apples. And experienced pickers had higher productivity levels than inexperienced ones in a majority of situations.

Male workers were found to have significantly faster apple picking rates than female workers in this study. And workers from 26 to 50 years old had significantly higher productivity than workers in either younger or older age categories.

Workers picking apples for the fresh market harvested significantly fewer bushels of apples per hour than did workers picking apples for processing. Picking apples in "good" weather was expected, a priori, to increase worker productivity, but picking rates in "good" weather were significantly lower than those in weather classed as "bad".

Statistical evidence of differential predictability for worker unit subgroups in this study was not strong although several variables did tend to show differential predictability for workers in different subgroups. There was evidence, however, supporting the hypothesis that apple picking labor is not homogeneous.

A tendency toward differential predictability was found for picking units of different sizes when apples were being picked for the fresh market. The productivity of individual pickers was reduced less by picking for this market than was the productivity of groups of two or more pickers working together.

Subgroups of workers based on residence tended toward differential predictability with respect to worker unit age, sex, and experience; and with respect to bonus payment.

Subgroups based on sex and ethnic origin were each found differentially predictable with respect to only one variable. Mixed male and female picking units had significantly faster picking rates when they received no bonus payment than did all-male units under the same conditions. And colored workers picked significantly more bushels of apples per hour than white pickers when only inexperienced pickers were considered.

AN ANALYSIS OF WORKER PRODUCTIVITY IN APPLE PICKING

By

Charles Michael Cuskaden

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1971

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to all those who assisted him in the preparation of this dissertation. Many more persons assisted in data collection, data processing, idea formulation, and preparing this dissertation draft than can be singularly given recognition here.

The author is especially indebted to Dr. L. V. Manderscheid, reigning major professor and thesis director, for his patient, but persistent, guidance in this research. To my major professors preceding Dr. Manderscheid, Drs. Nielson, Vincent, and Boyne, my appreciation for their guidance in my graduate studies.

Drs. Donald Ricks and Jack Wakeley who served on the dissertation guidance committee gave the author valuable help in formulating this study.

The author also wishes to express his appreciation to Drs. Daniel Sturt and Jack Hervey, formerly with the Rural Manpower Center at Michigan State University, for their assistance in obtaining, and their cooperation in using, the worker productivity data upon which this study is based.

The Department of Agricultural Economics provided financial support throughout my graduate program at Michigan State University and for this study. Thanks are due Dr. L. L. Boger, former Chairman of the Department, and Dr. Dale E. Hathaway, Chairman, for the opportunity for graduate study and for financial support.

To my family, Nancy, Gregory, and Charles, thanks for waiting. Dad will be home tonight.

TABLE OF CONTENTS

LIST OF TABLES

TABLE		PAGE

TABLE		PAGE

CHAPTER I

INTRODUCTION

Many fruit and vegetable crops grown in Michigan are cultivated and harvested by seasonal hand labor. This type of labor has traditionally been paid on a piece-work basis and about half of the workers employed in the production of these crops were residents of states other than Michigan or foreign countries, particularly Mexico.

In 1964, 159,400 seasonal workers were employed on Michigan farms.[1] Of this total, 63,000 were inter-state domestic workers and 13,400 were foreign nationals. The termination of Public Law 78[2] before the start of the 1965 crop year in addition to a high level of industrial employment reduced the number of seasonal farmworkers employed in Michigan in 1965 by about 3 percent compared to 1964.[3] Table 1 below illustrates the magnitude of the reduction in foreign workers admitted to the United States for season agricultural employment.

---

[1]William H. Metzler, Ralph A. Loomis, and Nelson L. LeRoy, "The Farm Labor Situation in Selected States, 1965-66," Agricultural Economics Report No. 110, ERS, USDA, April 1967, p. 34.

[2]The purpose of Public Law 78 was to supply agricultural workers from the Republic of Mexico to aid in the production of agricultural commodities in the United States. Public Law 78 contained, among others, provisions authorizing the Secretary of Labor of the United States to recruit and transport Mexican agricultural workers. All provisions of Public Law 78 may be found in Statutes at Large, Vol. 65, 1951, 82nd Congress of the United States of America.

[3]"The Farm Labor Situation in Selected States, 1965-66," op. cit., p. 34.

Table 1. Foreign Workers Admitted for Temporary Employment by Year and Nationality, 1958-67[a]

Year	Total	Mexican	British West Indian	Canadian	Japanese and Filipino
1958	447,513	432,857[b]	7,441	6,900	315
1959	455,420	437,643[b]	8,772	8,600	405
1960	334,729	315,846[b]	9,820	8,200	863
1961	310,375	291,420[b]	10,315	8,600	40
1962	217,010	194,978[b]	12,928	8,700	404
1963	209,218	186,865[b]	12,930	8,500	923
1964	200,022	177,736[b]	14,361	7,900	25
1965	35,871	20,284	10,917	4,670	0
1966	23,524	8,647	11,194	3,683	0
1967	23,603	6,125	13,578	3,900	0

[a]Farm Labor Developments, Bureau of Employment Security, U. S. Department of Labor, February, 1968, p. 14.

[b]Admitted under Public Law 78.

The tighter seasonal farm labor market coupled with increased pressure from civic groups and legislative bodies to improve the conditions under which seasonal agricultural employees live and work has stimulated the development and adoption of mechanized harvesting equipment for many fruit and vegetable crops produced in Michigan.

Although some experimental work has been done to mechanize apple harvesting in Michigan, it is still primarily a job for a man and a ladder. The 1964 Michigan production of apples on about 4,000 farms was approximately 692.4 million pounds which was valued at slightly over 22.1 million dollars.[4] Approximately 12,500 seasonal

[4]1964 United States Census of Agriculture, U. S. Department of Commerce, Bureau of the Census, Part 13, Michigan.

workers were used to harvest the Michigan apple crop in that year and they were paid about 3.7 million dollars for their labor.[5]

Fisher has shown that under conditions of perfect competition in both the product market and the harvest labor market that it will be to the benefit of growers to have a larger rather than a smaller work force when apples are being picked by piece-rate.[6] Under the conditions outlined above the decision to harvest an apple crop is an all or nothing decision since both the marginal revenue curve and the marginal cost curve for the firm are perfectly elastic.[7] With these two conditions existing the total number of man-hours of labor (in units of standard efficiency) is determined by the quantity of apples available to be harvested. Given the above conditions the grower will prefer more

---

[5]"The Farm Labor Situation in Selected States, 1965-66," op. cit., pp. 39 and 44.

[6]Lloyd H. Fisher, The Harvest Labor Market in California, Cambridge: Harvard University Press, 1953, pp. 151-160. Fisher's discussion is in terms of the harvest market in general, not specifically for apples, but his findings are directly applicable to the harvesting of apples. The grower will prefer a larger work force to a smaller one up to the point where the orchard becomes so crowded that damage occurs due to an extreme concentration of workers in one area.

[7]Ibid., pp. 151-155. The marginal revenue curve is perfectly elastic under the assumption of perfect competition in the product market. The perfectly elastic marginal cost curve is a direct result of the piece-rate method of payment. In developing his argument, Fisher assumes that labor cost is the only harvest cost. This ignores some minor items of harvest cost such as picking crates, but these costs are minimal compared to those of labor.

workers to fewer workers because this will shorten the time required to harvest the apple crop; and risk is reduced in this way.[8]

A reduction in the total number of seasonal workers available for employment on farms may result in growers experiencing the following two problems, among others. First, difficulty in recruiting seasonal labor and, second, difficulty in completing the harvesting of a crop during the period of peak quality. The main focus of this study will be on the efficient utilization of the available supply of seasonal labor by growers in order to minimize these two problems. More efficient utilization of a given number of harvest workers should have the same effect as increasing the number of workers in a harvest crew--risk should be reduced.

Studies of Hired Labor

The literature on agricultural labor can be separated into three general types: 1) that concerned with characteristics of the laborers themselves, 2) that concerned with labor mobility, and 3) econometric studies of labor market relationships. The United States Department of Agriculture has published a series on the hired farm working force annually since 1945.[9] This series gives information on the number of days of farm wage work and wages earned by selected worker characteristics on an aggregate United States basis.

---

[8] Increasing the number of workers to shorten harvest time is of concern to the grower for several reasons: 1) minimizes fruit spoilage, 2) lowers risk of weather damage, 3) avoids product price fluctuations, 4) maximizes time span of control over crop, and 5) prevents selective picking by workers of that part of the crop which is easiest to pick and yields more return to workers per unit of time.

[9] For example, see "The Hired Farm Working Force of 1968," _Agricultural Economic Report No. 164_, ERS, USDA, 1969. Prior to 1962 this series was published as an Agricultural Information Bulletin by AMS, USDA.

Numerous reports on mobility as a characteristic of the population of the United States are available in the literature. Numerically, sociologists have probably made the greatest contribution in this area.[10] Economists have also been concerned with labor mobility since this quality of labor is necessary for efficient use of resources in a dynamic economy such as exists in the United States.[11] Agricultural economists have mainly been concerned with the rural to urban labor flow as it relates to the relatively low labor return in agriculture compared to alternative employment opportunities.

Economists have also attempted to analyze the structure of the hired farm labor market empirically.[12] Statistical estimates have been made of both demand and supply relationships for hired farm labor. These studies have treated labor as a homogeneous input and have been concerned with the estimation of aggregate labor market relationships. This is in contrast to one of the basic assumptions of this study which is that labor is not a homogeneous factor. Specifically, individual

---

[10]For examples of this type of literature see: Paul J. Jehlik and Ray E. Wakeley, "Population Change and Net Migration in the North Central States, 1940-50," Iowa Agricultural Experiment Station Research Bulletin 430, July 1955, and Gladys K. Bowles, "Migration Patterns of the Rural-Farm Population, Thirteen Economic Regions of the United States, 1940-50," Rural Sociology, Vol. 22, 1957, pp. 1-11.

[11]For example, see: C. E. Bishop, "Economic Aspects of Changes in Farm Labor Force," in Labor Mobility and Population in Agriculture, Ames: Iowa State University Press, 1961.

[12]For example, see: 1) Zvi Griliches, "The Demand for Inputs in Agriculture and a Derived Supply Elasticity," Journal of Farm Economics, Vol. XLI, May 1959, pp. 309-322; 2) G. Edward Schuh, "An Economctric Investigation of the Market for Hired Labor in Agriculture," 3) T. D. Wallace and D. M. Hoover, "Income Effects of Innovation: The Case of Labor in Agriculture," Journal of Farm Economics, Vol. 48, May 1966, pp. 325-336.

differences exist with respect to worker unit productivity in apple harvesting. The individual with the highest level of performance under one set of conditions may not have the highest level of performance under some alternative set of conditions. Or two individuals having the same level of performance under some condition may not have the same performance level under another set of conditions.

Objectives

Three objectives were established for this study. The first was to investigate factors related to the productivity of workers being paid on a piece-work system for harvesting apples by hand.[13] The second objective was to determine whether the relationship between certain independent variables and worker productivity is different for specified subgroups within the total population of workers. Fulfillment of this objective may provide information allowing workers to be better placed according to the situation(s) in which they must work or it may point out certain practices which the grower could follow in order to better utilize his available supply of labor. The third objective of this study was to carry out a cross-validation[14] procedure using observations on worker productivity for the two years 1965 and 1966. This procedure entailed using 1965 data in a regression analysis to establish tentative relationships between picking rates and selected independent variables. The 1966 data were then used to check the relationship discovered in the 1965 data.

---

[13]The productivity of workers, or worker productivity, will be used throughout this study to refer to the rate of apple picking measured in bushels of apples picked per hour.

[14]The process of cross-validation involves the assessment of relationships for two separate samples within the same population.

CHAPTER II

PSYCHOLOGICAL CONCEPTS RELATED TO STUDY

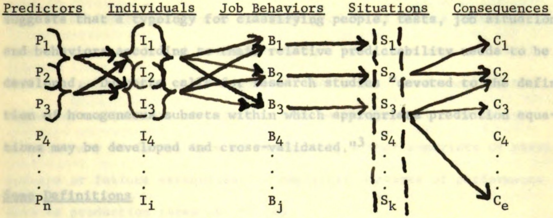
Prediction

Psychologists have for some time used statistical methods in attempts to predict future performance of individuals from present information. Most attempts have used psychological testing procedures which measure certain traits which the individual possesses. The relationship between the measured traits and later performance on the job, which is used as a criterion, is used to set up standards for selection of individuals for certain positions. The basis for this type of selection procedure rests on the assumption that the relationship between an individual's traits and his later success on the job will hold across individuals. Until recently most studies in this area used a simple Pearsonian Correlation Coefficient to assess the relationship between the criterion and the traits measured. This approach is based on a simple model containing only two variables: 1) a predictor, and 2) a criterion.

Recently, psychologists have begun to consider more complicated models for predicting the future performance of individuals. These models suggest that not all groups of people will be predictable to the same extent; that not all jobs within some broad category such as salesmen will be predictable to the same degree with a certain test; and that a particular test may be more useful in one situation than in another.

One such model has been discussed by Dunnette.[1] He has drawn upon the previous work of Guetzkow and Forehand[2] in proposing a model for personnel selection composed of five components.

Prediction Model Proposed by Dunnette



Dunnette suggests that this formulation for a prediction model takes account of the complex interactions which may occur between predictors and various predictor combinations, different groups (or types) of individuals, different behaviors on the job, and the consequences of these behaviors relative to the goals of the organization. The model permits the possibility of predictors being differentially useful for predicting the behaviors of different subsets of individuals. It shows that similar job behaviors may be predictable by quite different patterns of interaction between groupings of predictors and individuals or even

---

[1]Marvin D. Dunnette, "A Modified Model for Test Validation and Selection Research," Journal of Applied Psychology, Vol. 47, No. 5, 1965, pp. 317-23.

[2]Harold Guetzkow and Garlie A. Forehand, "A Research Strategy for Partial Knowledge Useful in the Selection of Executives," In: Research Needs in Executive Selection, Renato Tagiuri (Editor), Boston: Harvard Graduate School of Business Administration, 1961.

that the same level of performance on predictors can lead to substantially different patterns of job behavior for different individuals. The model also recognizes the annoying reality that the same or similar job behaviors can, after passing through the situational filter, lead to quite different organizational consequences. The Dunnette Model suggests that a typology for classifying people, tests, job situations, and behaviors according to their relative predictability needs to be developed. Dunnette calls for research studies "devoted to the definition of homogeneous subsets within which appropriate prediction equations may be developed and cross-validated."[3]

Some Definitions

Criterion - A criterion is a measure of success on a particular job or task.[4] Several criteria may exist for any particular job and a really complete ultimate criterion is multiple and complex in almost every case. Three categories of criteria are suggested by Thorndike:[5] 1) ultimate, 2) intermediate, and 3) immediate. An ultimate criterion is complete in the sense that there is no further or higher standard by which performance can be judged. An ultimate criterion may be inaccessible or involve a long time lag. For this reason criteria which are more immediately available and judged to be related to the ultimate criterion are of more practical importance. Thorndike refers to these criteria as intermediate and immediate.

---

[3]"A Modified Model for Test Validation and Selection Research," op. cit., p. 320.

[4]Robert L. Thorndike, Personnel Selection, New York: John Wiley & Sons, Inc., 1949, p. 119.

[5]Ibid., p.121.

Two types of criterion measures may be used in practice.[6] The first of these is the evaluation of performance on one specific task. A general summary evaluation of a total phase of on-the-job performance may also be used. All criterion measures must have some degree of validity and reliability. The validity of a criterion measure usually must be estimated largely on rational grounds as to its relevance to some ultimate goal.[7] A criterion measure must have some reliability, that is, reliability must be greater than zero. Assessment of the degree of reliability of criteria must be statistical. Criterion measures may be in the form of rankings by either superiors or peers, success or failure categories, or empirical measures of performance such as production rates on the job.

Predictor Variables - A predictor variable is one which can be observed or measured at the present time and has some relationships to future success on a particular job. In a regression analysis these variables would take the form of independent variables.

Validity - The validity of a measurement procedure depends upon its correlation with some measure of success in the job for which it is being used as a predictor. Wood[8] lists four ways in which validity may be assessed: 1) predictive, 2) concurrent, 3) construct, and 4) content. Predictive validity and concurrent validity are assessed empirically. Predictive validity is evaluated using some form of correlation coefficient to measure the relationship between the measurement technique

---

[6] Ibid., p. 132.

[7] Ibid., p. 125.

[8] Dorothy Adkins Wood, Test Construction, Columbus, Ohio: Charles E. Merrill Books, Inc., 1961, pp. 16-19.

in question and some later measure of performance in the job for which it is being used as a predictor. The assessment of concurrent validity utilizes the same empirical techniques as does the assessment of predictive validity. However, the criterion measure used is obtained at the same time as readings are taken on the predictor variable(s). The assessment of construct and content validity depends largely upon personal judgement.

<u>Reliability</u> - This concept is concerned with the extent that repeated measurement gives consistent results for the individual--consistent in that his score remains substantially the same when the measurement is repeated, or in that his standing in the group shows little change.[9] The degree of reliability in a set of measurements is determined by comparing error variance with the total variance. Reliability is high if the amount of error variance is low relative to the variation between persons and reliability is low if the amount of error variance is high relative to the variation between persons. Error variance is that part of total variance associated with a particular set of measurements which would not be reproduced on subsequent measurements. A reliability coefficient is generally calculated and used to represent the degree of reliability. This coefficient is computed by calculating the coefficient of correlation between two sets of scores.

The following are some of the methods commonly used to determine the degree of reliability in a set of measurements:[10] 1) equivalent

---

[9] Personnel Selection, *op. cit.*, p. 68.

[10] Personnel Selection, *op. cit.*, p. 79.

test forms, 2) repetition of identical test forms, 3) subdivision of a single total test, and 4) analysis of variance among items.

Cross Validation - This process involves the assessment of the validity of a particular measurement device on two separate samples of individuals within the same population.[11] Generally the first sample of individuals is used to develop and refine a measurement device. The degree of correlation between the scores on the measurement device for the first sample and their scores on a criterion measure is determined. After the above procedure has been carried out using the first sample of individuals, a second sample of individuals (different from the first) is obtained from the same population. The measurement device developed and refined on the first sample is then applied without further alteration to the second sample of individuals and their scores on the measurement device are correlated with their scores on the criterion. If the measurement device is to be considered valid for prediction within the population sampled, essentially the same relationship must exist between the criterion and the measurement device for both samples.

Review of Psychological Literature Related to Study Area

Frederiksen and Melville[12] have reported on a study of differential predictability in the use of test scores. They attempted to identify subgroups of individuals for whom a test is especially

---

[11] G. C. Helmstadter, Principles of Psychological Measurement, New York: Appleton-Century-Crofts, 1964, pp. 131-133.

[12] Norman Frederiksen and S. Donald Melville, "Differential Predictability in the Use of Test Scores," Educational and Psychological Measurement, Vol. XIV, 1954, p. 647.

appropriate as a predictor. Their objective is based on the belief that a specific regression formula is not likely to be uniformly appropriate for every member of a group. Students were dichotomized with respect to compulsiveness: 1) on the basis of scores on the Accountant scale of the Strong Vocational Interest Blank, and 2) on the basis of reading speed in relation to ability. It was found that there was a tendency for the correlation between interest scales and average freshman grades in engineering to be higher for the "non-compulsive" students.

Frederiksen and Gilbert[13] later carried out a replication of the above study of differential predictability in which they found that "noncompulsive" students were more predictable than "compulsive" students. Two indicators of compulsiveness were again used with freshman engineering students as subjects. It was found that the correlation between Strong Vocational Interest Blank scores and average grades for freshman engineering students was higher for the "noncompulsive" group than for the "compulsive" group.

Ghiselli[14] has reported an attempt to improve the predictions made with a tapping and dotting test by differentiation of the individuals taking the test into two groups. A group of candidates for the job of taxi-cab driver were screened on the basis of high and low scores on an Occupational Level Inventory. One-third of the subjects

---

[13] Norman Frederiksen and Arthur C. F. Gilbert, "Replication of a Study of Differential Predictability," Educational and Psychological Measurement, Vol. XX, No. 4, 1960, p. 759.

[14] Edwin E. Ghiselli, "Differentiation of Individuals in Terms of Their Predictability," Journal of Applied Psychology, Vol. 40, No. 6, 1956, p. 374.

selected on the basis of lowest scores on the inventory had a considerably higher validity coefficient between the Tapping and Dotting test and the criterion which was production during the first 12 weeks of employment.

Grooms and Endler[15] used a group of 91 male college students to study the differential contribution to prediction of academic achievement from aptitude test scores made by grouping the subjects on the basis of high, medium, and low anxiety. Test Anxiety Questionnaire scores were used to separate the students into groups. They concluded that test anxiety serves as a modifier variable which enhances the predictability of actual grade averages from aptitude test scores. As used here a modifier variable is defined as an independent variable which when dichotomized or trichotomized leads to differential subgroup relationships between a predictor variable and a criterion variable.

Abelson[16] reported research to test whether the college grades of boys and girls were equally predictable. Three predictors were tested separately. These were: 1) high school grades, 2) aptitude test scores, and 3) high school grades and aptitude test scores in combination. The findings were that girls' college grades were more predictable from high school grades alone and from the combined high school grades and aptitude test scores. No significant sex differences were found using

---

[15]Robert R. Grooms and Norman S. Endler, "The Effect of Anxiety on Academic Achievement," Journal of Educational Psychology, Vol. 51, No. 5, 1960, p. 299.

[16]Robert P. Abelson, "Sex Differences in Predictability of College Grades," Educational and Psychological Measurement, Vol. XII, 1952, p. 638.

aptitude test scores along. The greater predictability of girls' college grades was attributed mainly to the greater homogeneity of these grades, i.e., the standard deviation of college grades was smaller for the girls than it was for the boys.

Theoretical Model

Generally, in economic studies, labor and other inputs are assumed to be homogeneous. That is, one unit of labor is a perfect substitute for any other unit of labor. A basic assumption underlying this study is that labor is not homogeneous. Specifically, individuals differ in their level of performance under specific conditions. The individual with the highest level of performance under one set of conditions is not necessarily the one with the highest level of performance under some alternative set of conditions. And that individual workers, or worker units, having inherently different abilities may perform at the same levels if placed in differing working conditions.[17]

Drawing on the Dunnette Model, the predictors utilized in this study are the worker unit characteristics of age, sex, ethnic origin, experience, size, and residence. The individuals in Dunnette's Model are represented here by the different worker units for which observations were made during data collection. Situations as visualized here are the alternative conditions under which apples were being picked by the worker units observed. These situations include both those considered to be under the control of the operator of the orchard and those

---

[17] The basis for these statements is the model developed by Marvin D. Dunnette which was discussed previously on page 8 of this report.

beyond his immediate control.[18] The consequences, or outcome, of any particular combination of individuals and situations in the Dunnette Model are measured here in terms of the number of bushels of apples picked per hour by a specific worker unit observed.

Ordinary least squares regression analysis was used in this study to empirically test the Dunnette Model. A null hypothesis that there was no difference in the relationship between situation and consequence for individuals having differing predictor characteristics is tested against the alternative hypothesis that the above relationship will differ for worker units having differing predictor characteristics.

---

[18]Examples of these two types of variables are given on page 20 of this report.

CHAPTER III

DATA COLLECTION AND METHOD OF ANALYSIS

The primary purpose for collecting the data on apple picking rates used in this study was to provide information to serve as a guide to the Wage Deviation Board of the Department of Labor for the State of Michigan. This Board was charged with establishing minimum piece-rates for harvesting various fruit and vegetable crops in Michigan, including apples, in compliance with legislation adopted in 1965 by the Michigan State Legislature.[1] The Rural Manpower Center of Michigan State University carried out the fieldwork to collect information for the Wage Deviation Board to use in its deliberations. The observations made when this field work was carried out included information which would allow an analysis of factors related to the picking rates of workers harvesting apples by hand under the piece-work system. The variables included were of three general types: 1) characteristics of the workers, 2) factors under the control of the farm operator, and 3) other factors not directly under the control of the operator or the workers.

The data were gathered by trained enumerators under the supervision of members of the staff of the Department of Agricultural Economics at Michigan State University. In 1965, 3,982 usable worker-day observations[2] were obtained, and 647 like observations were made in 1966.

---

[1]Michigan Public Act 296.

[2]Worker-day observations included the number of bushels of apples picked each day by each worker unit in addition to information on the variables hypothesized to be related to worker productivity for each day.

Observations were made on 36 farms in 1965 from September 10 through November 3. Ten farms were included in the 1966 sample, and observations were obtained from September 26 through October 21. About 560 worker groups[3] were observed in 1965. In 1966, observations were gathered on 95 such groups. Data were gathered from farms in Allegan, Ionia, Kent, and Van Buren counties in both 1965 and 1966. Several additional counties were represented in the observations taken in 1965.

The sampling techniques used to select farms on which data were collected in 1965 and 1966 were not exactly identical. A random sample of a master list of apple growers in Michigan was used in 1965 to select the farms used in data collection. In 1966 a different sampling technique was employed. In that year an area sample prepared by the Statistical Reporting Service of the U.S.D.A., in addition to a list of large farmers prepared by county agricultural extension agents, was used to obtain a list of apple growers for sampling. The area sample produced very few apple growers in the counties where data was collected in 1966. Therefore, the larger farms were heavily relied upon to provide data on worker productivity in that year.

The 1966 population of farms is different from that of 1965 at least with respect to the size of farm. However, this study focuses on worker productivity and there is no reason to expect differences in worker performance due to differing farm sizes. Therefore statistical

---

[3]A work group (worker unit) consisted of one person working alone or several persons who worked together and pooled their apples and were paid as a group.

tests are calculated to test the differences in worker productivity between the two years for statistical significance.

In 1965 the arithmetic mean of the 3,982 observations on the dependent variable (bushels of apples picked per hour per worker) was 9.61 bushels. The standard deviation of the dependent variable in that year was 4.38 bushels. The following year the arithmetic mean of the dependent variable was 8.97 bushels for 647 observations, and this variable had a standard deviation of 3.29 bushels. A test of the difference between the sample means obtained for the dependent variable in the two years observed resulted in the rejection of the hypothesis that there was no difference between them.[4]

A test outlined by Johnston[5] was used to check whether or not the observations taken in 1966 came from the same relationship as those taken in 1965. Regression coefficients were estimated separately for each of the two years using the same regression model. The null hypothesis that $\beta_1 = \beta_2 = \beta$ was then tested against the alternative that $\beta_1 \neq \beta_2$.[6] This test of equality between coefficients in two regression relationships led to the rejection of the null hypothesis. This suggests that either the workers observed in these two years came from different populations; or that some independent variable(s) important in explaining variation in worker productivity differed between years, but was not observed in the data gathering process. This test result

---

[4]The form of this test and the calculations involved are presented in the Appendix.

[5]J. Johnston, Econometric Methods, New York: McGraw-Hill Book Company, Inc., 1963, pp. 136, 137.

[6]The β's are vectors of regression coefficients with β_1 and β_2 being the coefficients for 1965 and 1966, respectively. The form of this test and the calculations involved are presented in the Appendix.

also suggests that the two years 1965 and 1966 should be separated for purposes of data analysis and discussion of results. However, more importance may be attached to variables which show similar relationships to worker productivity in both 1965 and 1966, given the above test results, than if the null hypothesis had been accepted since these relationships may be expected to hold under a wider range of conditions.

Description of Variables Analyzed in Study

Observations on 19 independent (predictor) variables were used in developing models to analyze factors related to worker productivity in this study. These 19 predictor variables were classified into three basic types: 1) people variables, 2) variables under farm operator control, and 3) variables not under farm operator control. The variables classified in each of the three categories are given below.

People Variables	Variables Under Operator Control	Variables Not Controlled by Operator
Worker Unit Age	Type of Picking	Tree Age
Worker Unit Sex	Degree of Tree Pruning	Topography of Orchard
Worker Unit Size	Type Market Picked for	Weather Conditions
Worker Unit Experience	Rate of Pay	Tree Spread
Worker Unit Ethnic Origin	Bonus Paid	Fruit Size
Worker Unit Residence	Type of Supervision	
	Type of Picking Equipment	
	Tree Height	

The dependent (criterion) variable used in this study was bushels of apples picked per hour.[7]

[7] If a worker unit consisted of more than one person the dependent variable was measured in bushels of apples picked per hour per person in the worker unit, i.e., the arithmetic average was used.

<u>People Variables</u>.

None of the variables in this group were analyzed as continuous variables. The six variables observed were taken to be either dichotomous or trichotomous for purposes of the regression analysis. Picking unit size, experience, and residence were entered as dichotomous variables, while picking unit age, sex, and ethnic origin were considered as trichotomous.

<u>Worker Unit Age</u>. The age of each individual picker was recorded in years making it a discrete variable. In case a unit was made up of more than one person, the average age of all the individuals in the unit was used to represent the age of the unit. This variable was later trichotomized after a preliminary analysis indicated that it was not linearly related to the dependent variable used in the regression equations. The three categories used in trichotomizing picking unit age consisted of: 1) less than 26 years old, 2) 26-50 years old, and 3) over 50 years old.

<u>Worker Unit Sex</u>. Worker unit sex was not a quantifiable variable. A qualitative measure of this variable was made by classifying each worker unit into one of three categories: 1) male, 2) female, or 3) mixed male and female. The last category was applicable only in case two or more persons worked together.

<u>Worker Unit Size</u>. Picking unit size was determined by a count of the number of persons working together and being paid as a unit. This variable is by nature discrete, but it was dichotomized in order to examine differences between units consisting of a single individual and those containing two or more persons. Most of the units containing more than one person were family groups consisting of husband and wife.

Since these apple harvest data were collected in the fall after the start of the school year, they contain very few observations on units containing children of school age.

<u>Worker Unit Experience</u>. The picking unit experience variable was a measure of the number of years of apple picking experience the unit had prior to the year in which observations were made. It was also discrete by nature, but dichotomized in the statistical analysis. The two categories used in the analysis were designed to separate units having little or no experience (less than two years) from more experienced units. In case the experience of different individuals within a given unit was not uniform, an arithmetic average was used to represent the experience of the group.

<u>Worker Unit Ethnic Origin</u>. The ethnic origin of each worker unit was determined to be: 1) white, 2) colored, or 3) Mexican or Puerto Rican. Puerto Rican workers were grouped with workers of Mexican ethnic origin because too few Puerto Rican workers were observed to permit analyzing them as a separate group and they were judged to be more similar to the workers of Mexican ethnic origin than either of the other two categories.

<u>Worker Unit Residence</u>. The place of residence of the picking unit was not a quantifiable variable. The residence of the unit was recorded as the state which the individuals in the unit claimed as their permanent residence. The variable was then dichotomized into those claiming Michigan as their residence and those claiming other states as their residence. This was done to separate these seasonal workers into migrant and nonmigrant categories.

<u>Variables Under Operator Control</u>

Only one variable in this group was entered into the regression equations as a continuous variable. This was the rate of pay per bushel of apples which the pickers received. All of the other variables in this group were analyzed as dichotomous variables with the exception of the degree of tree pruning. The pruning variable was trichotomized in the regression analysis.

<u>Type of Picking</u>. The type of picking variable was an indication of whether apples were picked such that the stems remained on all apples or whether the apples were picked without regard for stems. Whether apples were picked with or without regard for stems was not directly observed. The variety of apple being picked was used as a proxy variable for type of picking. For purposes of this study the Delicious variety was assumed to be picked with all stems on and all other varieties were assumed to be picked without regard for stems.

<u>Degree of Tree Pruning</u>. Tree pruning was the only variable in this group which was analyzed as a trichotomous variable. An "A" pruned tree was one which was well pruned to permit maximum light penetration and was generally associated with apples being picked for the fresh or retail market. The trees which were classed in category B with respect to pruning had been pruned, but not to the extent of those in the A category. The last pruning category, C, contained trees which had received very little or no pruning.

<u>Type of Market Picked for</u>. This variable indicated whether the apples being picked would be sold as whole, fresh apples or would be processed into various types of canned or frozen products. It would be expected that this variable would be correlated with the type of

picking variable to a certain degree since processing apples can generally be picked without regard for stems while certain varieties of apples sold as fresh fruit are always packed with their stems on. This type-of-market variable is by nature qualitative and it was dichotomized as indicated above.

Rate of Pay. The amount paid to workers for picking apples was recorded in units of dollars and cents per bushel of apples picked. A linear relationship between the rate of pay and worker productivity was assumed in formulating the regression equations used in data analysis.

Bonus Paid. In some cases the farm operator will promise workers an additional payment at the end of the harvest season if they will work in his orchard until the end of the season. The amount of this bonus payment which the operator was promising to pay, if any, was recorded in units of cents per bushel. Although not dichotomous by nature, this variable was dichotomized in the regression analysis to analyze the effects of bonus payment on productivity. The variable as used in the analysis indicated whether or not a bonus was paid.

Type of Supervision. The type of supervision was a variable used to give some indication of the employer-employee relationship on a given farm. This qualitative variable was dichotomized into two broad categories: 1) close supervision, and 2) little or no supervision.

Type of Picking Equipment. The types of picking equipment used by workers observed during this study were grouped into two classes for purposes of analysis. Picking equipment refers to the sacks, buckets, or other containers used to hold apples which are carried by pickers. Although this variable is not quantifiable by nature, it is not necessarily dichotomous. It was dichotomized before being used in the regression analyses in order to examine differences between metal containers and canvas or other types of containers.

Tree Height. Tree height is a variable which can be quantified. Observations on this variable were made by recording the average height of the trees being picked by a particular worker unit on a given day. This variable was dichotomized before being analyzed in order to get some indication of the effect of topping trees on the productivity of pickers. Trees are generally topped at approximately 18 feet, so this height was used to separate trees into two categories: 1) tall (over 18 feet), and 2) medium (14-18 feet). A third category had been anticipated, but not enough observations were made for trees less than 14 feet tall to permit a short tree category to be included in the regression analyses. Any observations on worker units picking in trees under 14 feet tall were deleted from the data for both 1965 and 1966 before regression analysis.

Variables Not Controlled by the Operator

The variables in this group contained those which seemed to be beyond the control of the operator during the year in which data were gathered. Three of the five variables in this group were measured quantitatively; however, one of these was later dichotomized before being analyzed.

Tree Age. This variable was measured quantitatively and assumed to be linearly related to worker productivity in setting up regression equations. The age of trees being picked by worker units was recorded in years.

Topography of Orchard. The topography of the orchard being picked was recorded as being either level to gently rolling or hilly.

It was, therefore, used as a dichotomous variable in all regression equations.

Weather Conditions. This variable was a composite of three factors assumed to affect the performance of workers picking apples. The three factors used to construct the composite weather variable were: 1) temperature, 2) wind, and 3) moisture. The final weather variable was dichotomous and indicated whether the weather was good or bad for picking apples. The two weather categores were set up a priori based on the judgment of those developing the questionnaire used in data collection as to what constituted good and bad weather for picking apples. In order to be classed as good, weather conditions had to meet all of the following requirements: 1) temperature within the range of 55 to 75 degrees, 2) wind calm or gentle, and 3) moisture conditions dry. If any one of these three requirements was not met, weather conditions were classed as bad.

Tree Spread. The spread of a tree refers to the diameter of the area covered by the branches of a tree. A positive correlation would be expected between the spread of a tree and its age. Tree spread was quantitatively measured in feet and assumed to be linearly related to worker productivity in regression analyses.

Fruit Size. This variable was measured quantitatively by making a determination of the number of apples in a bushel. There was, therefore, an inverse relationship between the magnitude of this variable and the average size of the apples in a particular container. This variable was entered into regression equations as a dichotomous variable, however, in order to investigate productivity differences between workers picking small and medium sized apples. Apples were classed as small when a bushel contained more than 175 apples and medium when a bushel contained 125-175 apples. A breaking point between medium and small apples of 175 apples per bushel was chosen because 175 is an approximate figure for the maximum number of size 2 3/4 apples per bushel.[8] The use of a third category had been anticipated, but not enough large apples were picked to permit the use of a third category defined by fewer than 125 apples per bushel. Any observations on worker units picking large apples were deleted from the data for both 1965 and 1966 before regression analysis.

Method of Analysis

The principal method of statistical analysis used in this study was ordinary least squares regression analysis. This technique was used to determine the relationship between the rate at which workers picked apples and several worker characteristics, certain orchard characteristics, the worker-grower relationship, and certain external factors such as weather.

Four different steps were carried out in the regression analysis. These can be classified as follows:

1) Analysis of the total sample of workers in 1965.
2) Analysis of the total sample of workers in 1966.
3) Subgroup analysis based on worker characteristics using 1965 data.
4) Subgroup analysis based on worker characteristics using 1966 data.

[8] W. D. Pheteplace, Jr., "Manufacture of Applesauce in the Digestor or Pressure Cooker," Food Industries, Vol. 10, 1938, p. 224.

The general approach was to use the 1965 data to establish tentative relationships among the variables. These relationships were then checked by rerunning the regression equation established with 1965 data using the 1966 data. The relationships found to hold in both years were taken to be essentially correct.

Equations Used in Analysis

Seven different equations (models) were developed in this study to analyze factors related to the productivity of apple pickers. These equations were of two basic types--with and without interaction terms.

Model (1)

Only one model was developed which contained no interaction variables. It was of the form: $Y = a + b_1X_1 + b_2X_2 + \ldots + b_{23}X_{23}$, where the variables Y and X_1 through X_{23} were defined as follows:

Y = bushels of apples picked per hour per person

Type of Picking

X_1 = 1 if all apples picked with stems on, = 0 otherwise

(apples picked without regard for stems)[9]

---

[9]This and all the following categories of zero-one "dummy variables set off in parentheses were set equal to zero (omitted) in solving for the regression coefficients. For a discussion of this technique as well as other methods of solving for regression coefficients when "dummy" variables are used see: William G. Tomek, "Using Zero-One Variables with Time Series Data in Regression Equations," Journal of Farm Economics, Vol. 45, No. 4, November 1963, pp. 814-22.

Tree Age

X_2 = age of tree in years

Degree of Tree Pruning

X_3 = 1 if well pruned, = 0 otherwise

X_4 = 1 if some to moderate pruning, = 0 otherwise

(little or no pruning)

Type Market Picked For

X_5 = 1 if picked for retail market, = 0 otherwise

(picked for processing)

Topography of Orchard

X_6 = 1 if level to gently rolling, = 0 otherwise

(hilly)

Weather Conditions

X_7 = 1 if weather good, = 0 otherwise

(weather bad)

Rate of Pay

X_8 = rate of pay per bushel in dollars

Bonus Paid

X_9 = 1 if no bonus paid, = 0 otherwise

(bonus paid)

<u>Type of Supervision</u>

X_{10} = 1 if close supervision, = 0 otherwise

(little or no supervision)

<u>Type of Picking Equipment</u>

X_{11} = 1 if metal picking equipment, = 0 otherwise

(canvas or other picking equipment)

<u>Worker Unit Age</u>

X_{12} = 1 if worker age less than 26, = 0 otherwise

(worker age 26-50)

X_{13} = 1 if worker age over 50, = 0 otherwise

<u>Worker Unit Sex</u>

X_{14} = 1 if workers all female, = 0 otherwise

X_{15} = 1 if workers mixed male and female, = 0 otherwise

(workers all male)

<u>Worker Unit Size</u>

X_{16} = 1 if individual worker, = 0 otherwise

(two or more workers)

<u>Worker Unit Experience</u>

X_{17} = 1 if worker has less than two years experience, = 0 otherwise

(two or more years experience)

<u>Worker Unit Ethnic Origin</u>

X_{18} = 1 if colored worker, = 0 otherwise

X_{19} = 1 if Mexican or Puerto Rican worker, = 0 otherwise

(white worker)

<u>Worker Unit Residence</u>

X_{20} = 1 if Michigan resident, = 0 otherwise

(resident of state other than Michigan)

<u>Tree Spread</u>

X_{21} = tree spread in feet

<u>Tree Height</u>

X_{22} = 1 if tree height over 18 feet, = 0 otherwise

(tree height 14-18 feet)

<u>Fruit Size</u>

X_{23} = 1 if over 175 apples per bushel, = 0 otherwise

(125-175 apples per bushel)

Models (2)-(4)

An additional three equations used the variables outlined above and they were constructed as shown below.

Model (2): $Y = a + b_1X_1 + b_2X_2 + \ldots . + b_{23}X_{23} + b_{24}X_1X_{17} + b_{25}X_2X_{17} + \ldots . + b_{39}X_{16}X_{17} + b_{40}X_{18}X_{17} + \ldots . + b_{45}X_{23}X_{17}$

Model (3): $Y = a + b_1X_1 + b_2X_2 + \ldots . + b_{23}X_{23} + b_{24}X_1X_{16} + b_{25}X_2X_{16} + \ldots . + b_{38}X_{15}X_{16} + b_{39}X_{17}X_{16} + \ldots . + b_{45}X_{23}X_{16}$

Model (4): $Y = a + b_1X_1 + b_2X_2 + \ldots + b_{23}X_{23} + b_{24}X_1X_{20} + b_{25}X_2X_{20} + \ldots + b_{42}X_{19}X_{20} + b_{43}X_{21}X_{20} + \ldots + b_{45}X_{23}X_{20}$

These three equations were constructed using the dichotomous variables worker unit experience, worker unit size, and worker unit residence to form interaction terms as indicated above. The interaction terms were included in these models in order to investigate differences in the relationships between the independent (predictor) variables and the dependent (criterion) variable for the two subclasses of workers defined for each of the three variables: 1) worker unit experience, 2) worker unit size, and 3) worker unit residence.

Models (5)-(7)

The final three equations used in this study were developed using variables defined in the following manner:

Y = bushels of apples picked per hour per person

Type of Picking

X_1 = 1 if all apples picked with stems on, = 0 otherwise (apples picked without regard for stems)[10]

Tree Age

X_2 = age of tree in years

[10]As indicated previously, this and all the following "dummy" variable categories set off in parentheses were omitted in solving for regression coefficients.

<u>Degree of Tree Pruning</u>

X_3 = 1 if well pruned, = 0 otherwise

X_4 = 1 if some to moderate pruning, = 0 otherwise

(little or no pruning)

<u>Type Market Picked For</u>

X_5 = 1 if picked for retail market, = 0 otherwise

(picked for processing)

<u>Topography of Orchard</u>

X_6 = 1 if level to gently rolling, = 0 otherwise

(hilly)

<u>Weather Conditions</u>

X_7 = 1 if weather good, = 0 otherwise

(weather bad)

<u>Rate of Pay</u>

X_8 = rate of pay per bushel in dollars

<u>Bonus Payment</u>

X_9 = 1 if no bonus paid, = 0 otherwise

(bonus paid)

<u>Type of Supervision</u>

X_{10} = 1 if close supervision, = 0 otherwise

(little or no supervision)

<u>Type of Picking Equipment</u>

X_{11} = 1 if metal picking equipment, = 0 otherwise

(canvas or other picking equipment)

<u>Worker Unit Age</u>

X_{12} = 1 if worker age less than 26, = 0 otherwise

X_{13} = 1 if worker age 26-50, = 0 otherwise

X_{14} = 1 if worker age over 50, = 0 otherwise

<u>Worker Unit Sex</u>

X_{15} = 1 if workers all male, = 0 otherwise

X_{16} = 1 if workers all female, = 0 otherwise

X_{17} = 1 if workers mixed male and female, = 0 otherwise

<u>Worker Unit Ethnic Origin</u>

X_{18} = 1 if white worker, = 0 otherwise

X_{19} = 1 if colored worker, = 0 otherwise

X_{20} = 1 if Mexican of Puerto Rican worker, = 0 otherwise

<u>Worker Unit Size</u>

X_{21} = 1 if individual worker, = 0 otherwise

(two or more workers)

<u>Worker Unit Experience</u>

X_{22} = 1 if worker has less than two years experience, = 0 otherwise

(two or more years experience)

<u>Worker Unit Residence</u>

X_{23} = 1 if Michigan resident, = 0 otherwise

(resident of state other than Michigan)

<u>Tree Spread</u>

X_{24} = tree spread in feet

<u>Tree Height</u>

X_{25} = 1 if tree height over 18 feet, = 0 otherwise

(tree height 14-18 feet)

<u>Fruit Size</u>

X_{26} = 1 if over 175 apples per bushel, = 0 otherwise

(125-175 apples per bushel)

The variables defined for models (5)-(7) above are exactly the same as those previously defined for models (1)-(4) with the exception of three variables: 1) worker unit age, 2) worker unit sex, and 3) worker unit ethnic origin. Several additional independent variables were renumbered in models (5)-(7), but their definitions remained the same as when used in models (1)-(4). In contrast to the way they were defined for models (1)-(4) all three categories of the trichotomized variables worker unit age, worker unit sex, and worker unit ethnic origin were retained in constructing models (5)-(7), i.e., none of the three categories of these "dummy" variables were omitted in setting up models (5)-(7). Defining the above three variables in this manner facilitated testing for differences between regression coefficients for the three subgroups defined for each of them.

Models (5)-(7) were developed using the trichotomized variables worker unit age, worker unit sex, and worker unit ethnic origin in interaction terms as follows.

Model (5): $Y = a + b_1X_1X_{12} + b_2X_1X_{13} + b_3X_1X_{14} + b_4X_2X_{12} + b_5X_2X_{13} + b_6X_2X_{14} + \ldots + b_{31}X_{11}X_{12} + b_{32}X_{11}X_{13} + b_{33}X_{11}X_{14} + b_{34}X_{16}X_{12} + b_{35}X_{16}X_{13} + b_{36}X_{16}X_{14} + b_{37}X_{17}X_{12} + b_{38}X_{17}X_{13} + b_{39}X_{17}X_{14} + b_{40}X_{19}X_{12} + b_{41}X_{19}X_{13} + b_{42}X_{19}X_{14} + \ldots + b_{61}X_{26}X_{12} + b_{62}X_{26}X_{13} + b_{63}X_{26}X_{14}$

Model (6): $Y = a + b_1X_1X_{15} + b_2X_1X_{16} + b_3X_1X_{17} + b_4X_2X_{15} + b_5X_2X_{16} + b_6X_2X_{17} + \ldots + b_{34}X_{12}X_{15} + b_{35}X_{12}X_{16} + b_{36}X_{12}X_{17} + b_{37}X_{14}X_{15} + b_{38}X_{14}X_{16} + b_{39}X_{14}X_{17} + b_{40}X_{19}X_{15} + b_{41}X_{19}X_{16} + b_{42}X_{19}X_{17} + \ldots + b_{61}X_{26}X_{15} + b_{62}X_{26}X_{16} + b_{63}X_{26}X_{17}$

Model (7): $Y = a + b_1X_1X_{18} + b_2X_1X_{19} + b_3X_1X_{20} + b_4X_2X_{18} + b_5X_2X_{19} + b_6X_2X_{20} + \ldots + b_{34}X_{12}X_{18} + b_{35}X_{12}X_{19} + b_{36}X_{12}X_{20} + b_{37}X_{14}X_{18} + b_{38}X_{14}X_{19} + b_{39}X_{14}X_{20} + b_{40}X_{16}X_{18} + b_{41}X_{16}X_{19} + b_{42}X_{16}X_{20} + b_{43}X_{17}X_{18} + b_{44}X_{17}X_{19} + b_{45}X_{17}X_{20} + b_{46}X_{21}X_{18} + b_{47}X_{21}X_{19} + b_{48}X_{21}X_{20} + \ldots + b_{61}X_{26}X_{18} + b_{62}X_{26}X_{19} + b_{63}X_{26}X_{20}$

A test for difference in the interaction term regression coefficients associated with the three age subgroups of each independent variable of model (5) was made in conjunction with the computer solution for the coefficients of model (5). For example, in the case of the independent variable tree age (X_2) in model (5) the null hypothesis that $\beta_4 = \beta_5 = \beta_6$ was tested against the alternative that these coefficients for the three age subgroups were not equal. This test was made for each other independent variables in model (5). A similar testing procedure was carried out for models (6) and (7) using the sex and ethnic origin subgroups, respectively. This testing procedure was carried out in an attempt to identify differences which might exist in the relationship between the independent variables included in models (5)-(7) and the dependent variable for different subgroups of workers based on age, sex, and ethnic origin.

CHAPTER IV

RELATIONSHIP OF PEOPLE VARIABLES TO WORKER PRODUCTIVITY

The results of the regression analyses of models (1)-(7) for those variables classed as "people variables" are presented in this chapter. The variables of worker unit age, sex, size, experience, ethnic origin and residence will be considered in that order. The empirical results of models (1)-(7) for both the years 1965 and 1966 will be discussed for each of these six variables. The nine tables included in this chapter give the regression coefficients and standard errors obtained in models (1)-(7) for the variables under discussion. A complete listing of the regression coefficients and standard errors for all variables included in these models is given in Chapter VII.

Worker Unit Age

Pickers in the 26-50 age range were more productive in both 1965 and 1966 on the average than were either younger or older workers. These middle-aged workers had picking rates significantly[1] higher than either of the other two age groups in both years. Workers who were 51 years of age or older had the lowest productivity level of the three age subgroups in both years while the younger workers held the median position with respect to productivity in both years.

---

[1]When reference is made to significant or to significant difference; a statistical significance or a statistically significant difference at the 0.05 level should be understood in all cases unless specified otherwise.

Table 2. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Age Less Than 26

Model	Year		Variables		
				X_{12}	
(1)	1965	Coefficient		-0.424	
		Standard Error		0.162	
	1966	Coefficient		-1.290	
		Standard Error		0.296	
			X_{12}		$X_{12}X_{17}$
(2)	1965	Coefficient	-0.967		1.099
		Standard Error	0.242		0.327
	1966	Coefficient	-1.590		1.105
		Standard Error	0.427		0.625
			X_{12}		$X_{12}X_{16}$
(3)	1965	Coefficient	-0.028		-0.580
		Standard Error	0.277		0.342
	1966	Coefficient	-1.173		-0.266
		Standard Error	0.521		0.635
			X_{12}		$X_{12}X_{20}$
(4)	1965	Coefficient	-0.376		-1.307
		Standard Error	0.169		0.592
	1966	Coefficient	-1.201		0.066
		Standard Error	0.309		1.267
			$X_{12}X_{12}$*	$X_{12}X_{13}$*	$X_{12}X_{14}$*
(5)	1965	Coefficient	omit	omit	omit
		Standard Error			
	1966	Coefficient	omit	omit	omit
		Standard Error			
			$X_{12}X_{15}$	$X_{12}X_{16}$	$X_{12}X_{17}$
(6)	1965	Coefficient	-0.491	-0.639	-0.256
		Standard Error	0.204	0.524	0.313
	1966	Coefficient	-1.435	-1.314	-1.240
		Standard Error	0.389	1.211	0.524
			$X_{12}X_{18}$	$X_{12}X_{19}$	$X_{12}X_{20}$
(7)	1965	Coefficient	-0.952	-0.324	-0.382
		Standard Error	0.249	0.333	0.285
	1966	Coefficient	-1.389	-0.594	-0.822
		Standard Error	0.393	0.523	1.394

*Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

Having one or fewer years of experience picking apples reduced the productivity of younger pickers less than that of middle-aged workers in both 1965 and 1966. The interaction term for worker unit experience and worker unit age for the younger pickers approached being significant at the .05 level in both years.[2] The interaction effects of worker unit experience and worker unit age were not consistent for the workers more than 50 years old in these two years. In 1965 the productivity of these older workers was reduced less than that of middle-aged pickers by having limited apple picking experience, but in 1966 the picking rates of the older workers were reduced more than those of the middle-aged workers in this situation. This worker unit age-worker unit experience interaction term for the pickers over 50 years old was significant in only 1965. In 1965, when only workers with no more than one year of experience were considered, the pickers in the youngest age group had higher picking rates than either of the other two age groups; with workers over 50 years old having the lowest rates. But in 1966 the younger pickers out-performed only the workers over 50 years old when only inexperienced units were considered. When worker units with more than one year of experience were considered, the relative picking rates[3] of the three age groups were more consistent in these two years than were those of the inexperienced picking units. Among experienced units,

---

[2]In 1965 it was significant at the 0.001 level and in 1966 it was significant at the 0.074 level.

[3]Relative picking rates, or relative productivity, is determined by the relative magnitudes of the regression coefficients for the variables in question, i.e., 1.276 is greater than -0.234 is greater than -1.725.

Table 3. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Age Over 50

Model	Year		Variables		
				X_{13}	
(1)	1965	Coefficient		-2.007	
		Standard Error		0.218	
	1966	Coefficient		-1.621	
		Standard Error		0.302	
			X_{13}		$X_{13}X_{17}$
(2)	1965	Coefficient	-2.501		2.097
		Standard Error	0.244		0.560
	1966	Coefficient	-1.444		-0.106
		Standard Error	0.387		0.794
			X_{13}		$X_{13}X_{16}$
(3)	1965	Coefficient	-2.132		0.063
		Standard Error	0.399		0.477
	1966	Coefficient	-1.012		-0.925
		Standard Error	0.564		0.676
			X_{13}		$X_{13}X_{20}$
(4)	1965	Coefficient	-1.826		-0.490
		Standard Error	0.285		0.453
	1966	Coefficient	-1.258		-1.450
		Standard Error	0.336		1.221
			$X_{14}X_{12}$*	$X_{14}X_{13}$*	$X_{14}X_{14}$*
(5)	1965	Coefficient	omit	omit	omit
		Standard Error			
	1966	Coefficient	omit	omit	omit
		Standard Error			
			$X_{14}X_{15}$	$X_{14}X_{16}$	$X_{14}X_{17}$
(6)	1965	Coefficient	-2.175	-0.959	-2.296
		Standard Error	0.272	0.782	0.423
	1966	Coefficient	-2.086	-0.701	-0.931
		Standard Error	0.391	1.398	0.562
			$X_{14}X_{18}$	$X_{14}X_{19}$	$X_{14}X_{20}$
(7)	1965	Coefficient	-2.422	-1.559	-2.917
		Standard Error	0.281	0.425	0.719
	1966	Coefficient	-1.499	-1.109	-1.100
		Standard Error	0.365	0.678	2.290

*Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

the middle-aged pickers had the highest productivity levels in both 1965 and 1966. The younger units ranked next in productivity in both of these years among experienced pickers; while workers over 50 had the slowest picking rates in both years. Within specific age subgroups, picking units having more than one year of experience had the fastest picking rates in both 1965 and 1966 only in the case of middle-aged workers. In the cases of picking units less than 26 years old and over 50 years old, experienced pickers did not out-perform less experienced ones in both years. Within both of these age groups, pickers with less than two years of experience had the highest productivity in 1965, while in 1966 the more experienced units had the highest picking rates.

The productivity of workers less than 26 years old was lower on the average than that of middle-aged pickers in both 1965 and 1966. And the productivity of younger workers who picked alone was reduced even more in both of these years than that of units of the same age who worked in groups of two or more. This interaction term was not significant in either year, however. Pickers more than 50 years old had lower picking rates than middle-aged pickers in both 1965 and 1966 on the average, as did young pickers. But the interaction of picking unit size and picking unit age for the older workers was not consistent between years. In 1965, the productivity of older workers picking alone was reduced less than that of those working in groups of two or more. But in 1966 the picking rate of the older workers picking alone was reduced more than that of those working with other pickers. This interaction term for the older workers was not significant in either year. When the productivities of the young and old pickers working alone are compared, the young workers had faster picking rates in both years.

Among working units which were residents of Michigan, those 26-50 years of age had the highest productivity in both 1965 and 1966. These middle-aged workers were followed in both years by pickers less than 26 years old in order of their picking rates, while older Michigan residents had the slowest picking rates. When the relative picking rates of units in different age groups who were not Michigan residents were compared, the middle-aged worker units again had the fastest picking rates in both years. Workers falling in the two other age groups who were not residents of Michigan occupied the same relative positions with respect to productivity as did workers in these age groups who were Michigan residents. Regardless of which age subgroup was being considered, nonresidents had higher productivity levels in both 1965 and 1966 than did Michigan residents when the performance of residents and nonresidents within any particular age group was examined.

The picking rates of workers less than 26 years old were lower in both 1965 and 1966 than those of the average worker 26-50 years old regardless of which sex group the younger workers were in. Male pickers in the younger age category were the only ones having significantly lower picking rates than the average picker 26-50 years old in both years, however. Within the younger age group, the mixed male and female units had the fastest picking rates of the three sex subgroups in both 1965 and 1966. The productivity levels of the male, female, and mixed male and female units which were less than 26 years old were not significantly different from each other in either year. Nor did workers in these three sex subgroups who were over 50 years old differ significantly with respect to productivity in either year. Within this older age group female worker units had the fastest picking rates in both 1965 and 1966. The productivity of these older female units did not differ significantly from that of the average unit 26-50 years of age in either year. All three types of sex subgroups in which the pickers were over 50 years old did have lower picking rates than the average 26-50 year-old picker in both years, however. But the male units in this age group, as was the case in the youngest age group, were the only ones having significantly lower productivity than the average middle-aged picker in both years.

Even though the picking rates of workers in different ethnic subgroups were not significantly different from each other in either year for workers who were less than 26 years old, a pattern did hold in both 1965 and 1966 with respect to the relative productivity of these ethnic subgroups. Within the younger age group colored worker units had the highest picking rates in both years. White worker units had the lowest productivity in both years among young workers; while the Mexican and Puerto Rican units occupied a median position with respect to productivity in both years. All of the young ethnic subgroups had picking rates in both of these years which were less than the average rate of all units made up of workers 26-50 years of age. Only the white workers among the younger group, however, had productivity levels significantly lower than the average middle-aged worker in either year; they had significantly lower picking rates in both 1965 and 1966. The pattern observed in the relative productivity of the three ethnic subgroups of young workers did not hold for worker units over 50 years old. For these older units colored pickers had faster picking rates than white units in both 1965 and 1966. But the Mexican and Puerto Rican pickers in this older age group did not hold a median position with respect to productivity in either year as was true for the workers under 26 years old. These Mexican and Puerto Rican worker units had the lowest picking rates of the three ethnic subgroups in 1965, but in 1966 they had the highest rates. The ethnic subgroups in the older age group did not differ significantly from each other in either year with respect to productivity. All of the ethnic subgroups in this age group had significantly lower picking rates in 1965 than the average worker unit 26-50 years old. However, only the older white pickers differed significantly from the average middle-aged picker in both 1965 and 1966 even though all older ethnic subgroups had lower productivity levels than the average middle-aged picker in both years.

Worker Unit Sex

Male picking units on the average over all situations had faster picking rates than either female or mixed male and female units in both 1965 and 1966. The productivity of only the female picking units was significantly less than that of the male units in both years, however. The mixed male and female units had picking rates significantly lower than those of males in 1965, but not in 1966.

Model (2) indicated that male picking units were more productive than female units in both 1965 and 1966 as long as only units with more than one year of apple picking experience were considered. However, when only pickers with less than two years of experience were considered, male and female units did not have the same relative productivity in both years. In 1965, inexperienced males outperformed females with the same amount of experience, but in 1966, this relationship was reversed. The interaction term in this model between worker unit sex and worker unit experience picking apples was not significant in either year for the female units. An interaction term for mixed male and female units was not calculated due to insufficient data. When the productivities of picking units in different classes with respect to apple picking experience were compared, experienced pickers were found to rank higher than inexperienced ones of the same sex regardless of whether they were male or female.

Model (1) indicated that for the average female worker unit productivity was lower than for the average male worker unit in both 1965 and 1966. However, in model (3) the productivity of male units was higher than that of females only in 1965. The interaction of worker unit size with the female sex variable indicated that working alone, as opposed to working in a group, reduced the productivity of female units even more in 1965. In 1966 when model (3) showed females to have faster picking rates than males, this interaction term showed the productivity of female pickers working alone to be increased less than that of females working in groups. The regression coefficient for this interaction term was significant in 1966, but not in 1965. The cases in which a picking unit contains one person and is in the mixed male and female subgroup are mutually exclusive so no coefficient could be computed for an interaction term consisting of these two variables.

Male worker units out-performed female units on the average under all conditions in both 1965 and 1966. This relationship held true also when only non-residents of Michigan were considered, but not when Michigan residents were examined separately. For Michigan residents, female picking units had higher productivity levels than male units in 1966. The interaction term for female units between worker unit sex and worker unit residence approached being significant in both 1965 and 1966.[4] Male picking units also had higher productivity levels than mixed male and female units in both 1965 and 1966 as an average for all conditions. However, when residents and non-residents of Michigan were considered separately, the above relationship between the productivity of male units and mixed male and female units did not hold in both years. Both resident and nonresident male units had higher picking rates than mixed male and female units having similar residences in 1965. But in 1966 Model (4) suggests that the mixed male and female picking units had higher productivity levels than male units in the same residence category regardless of whether it was resident or nonresident.[5] In 1965 the relative productivity of the three sex subgroups was the same regardless of whether pickers were

---

[4]This term was significant at the 0.055 level in 1965 and at the 0.012 level in 1966.

[5]This apparent inconsistency may be explained by the fact that little confidence can be placed in the estimate of the regression coefficient for the interaction term: mixed male and female unit--Michigan resident. This coefficient had a standard error over ten times larger than the coefficient itself in model (4) for 1966.

Table 4. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Sex Female

Model	Year		Variables		
				X_{14}	
(1)	1965	Coefficient		-1.651	
		Standard Error		0.253	
	1966	Coefficient		-1.276	
		Standard Error		0.572	
			X_{14}		$X_{14}X_{17}$
(2)	1965	Coefficient	-1.703		-0.022
		Standard Error	0.324		0.520
	1966	Coefficient	-1.156		1.320
		Standard Error	0.638		2.049
			X_{14}		$X_{14}X_{16}$
(3)	1965	Coefficient	-1.097		-0.543
		Standard Error	0.650		0.709
	1966	Coefficient	5.766		-6.949
		Standard Error	2.362		2.436
			X_{14}		$X_{14}X_{20}$
(4)	1965	Coefficient	-2.145		1.037
		Standard Error	0.331		0.548
	1966	Coefficient	-2.145		1.037
		Standard Error	0.331		0.548
			$X_{16}X_{12}$	$X_{16}X_{13}$	$X_{16}X_{14}$
(5)	1965	Coefficient	-1.818	-2.094	0.522
		Standard Error	0.533	0.326	0.812
	1966	Coefficient	-9.348	-1.666	-0.457
		Standard Error	8.641	0.869	1.543
			$X_{16}X_{15}$*	$X_{16}X_{16}$*	$X_{16}X_{17}$*
(6)	1965	Coefficient	omit	omit	omit
		Standard Error			
	1966	Coefficient	omit	omit	omit
		Standard Error			
			$X_{16}X_{18}$	$X_{16}X_{19}$	$X_{16}X_{20}$[a]
(7)	1965	Coefficient	-1.084	-1.837	omit
		Standard Error			
	1966	Coefficient	-1.663	0.052	no data
		Standard Error			

Table 4 (cont'd.)

*Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

[a]"No data" signifies that no observations were made for the variable in the year indicated. The variable was dropped from the model for both years.

residents of Michigan or not. Their picking rates in order from high to low ranked: male, mixed male and female, and female. In 1966 the relative productivity of the three sex subgroups was not the same for residents and nonresidents of Michigan. Nor did the pattern of the three sex subgroups with respect to their relative productivity follow that of 1965 for either residence class. In this year, the mixed male and female units had the fastest picking rates among non-resident workers. They were followed by male units and female units in order of their productivity. When Michigan residents were considered separately in 1966, female worker units ranked highest in productivity followed by mixed male and female units and male units in that order. When nonresident and resident workers were compared within a given sex subgroup, nonresidents of Michigan were found to have higher productivity levels in both 1965 and 1966 than Michigan residents regardless of whether the units were in the male, female, or the mixed male and female category.

The productivity of female pickers over 50 years old was higher in both 1965 and 1966 than that of females in either of the other two age groups. The average picking rate of these older female workers was not significantly different from that of the average male picker in either 1965 or 1966. The picking rates of female worker units in the

Table 5. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Sex Mixed Male and Female

Model	Year		Variables		
				X_{15}	
(1)	1965	Coefficient		-1.281	
		Standard Error		0.317	
	1966	Coefficient		-1.402	
		Standard Error		1.147	
			X_{15}	$X_{15}X_{17}$ [b]	
(2)	1965	Coefficient	-1.292	omit	
		Standard Error	0.328		
	1966	Coefficient	-1.381	singular	
		Standard Error			
			X_{15}	$X_{15}X_{16}$*	
(3)	1965	Coefficient	-0.827	omit	
		Standard Error	0.369		
	1966	Coefficient	-0.452	omit	
		Standard Error	1.518		
			X_{15}	$X_{15}X_{20}$	
(4)	1965	Coefficient	-1.348	0.438	
		Standard Error	0.351	0.876	
	1966	Coefficient	1.203	-0.222	
		Standard Error	1.875	2.931	
			$X_{17}X_{12}$	$X_{17}X_{13}$	$X_{17}X_{14}$
(5)	1965	Coefficient	-2.279	-1.218	-1.964
		Standard Error	0.567	0.392	0.473
	1966	Coefficient	5.079	-2.024	-0.575
		Standard Error	2.835	1.561	0.707
			$X_{17}X_{15}$*	$X_{17}X_{16}$*	$X_{17}X_{17}$*
(6)	1965	Coefficient	omit	omit	omit
		Standard Error			
	1966	Coefficient	omit	omit	omit
		Standard Error			
			$X_{17}X_{18}$	$X_{17}X_{19}$ [b]	$X_{17}X_{20}$
(7)	1965	Coefficient	-1.740	omit	0.461
		Standard Error	0.547		0.596
	1966	Coefficient	-2.131	singular	-0.034
		Standard Error	1.470		2.919

Table 5. (cont'd.)

*Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

three age classes observed were significantly different from each other in 1965, but not in 1966. No one age group ranked highest or lowest in productivity for both 1965 and 1966 among mixed male and female picking units. The average productivity levels for the three age classes within this sex subgroup were not significantly different from each other in either year. Both the 26-50 year old age group and the over 50 age group among mixed male and female picking units had picking rates lower than the average male picking unit in both years. But the sign of the regression coefficient for young mixed male and female units was not the same in both 1965 and 1966.[6]

Female worker units of white and colored ethnic origin did not have the same relative productivity levels in both 1965 and 1966.[7] Nor were their picking rates significantly different from each other in either of these years. The productivity of the white female units was significantly lower than that of the average male picking unit in both years, while the productivity of the colored units in this subgroup differed significantly from that of the average male unit in

---

[6]Even though the signs of this coefficient were different in these two years, the coefficient approached significance at the 0.05 level in both years. In 1965, it was significant at less than the 0.0005 level and in 1966 at the 0.070 level.

[7]The available data for 1966 did not contain any observations on Mexican and Puerto Rican units in this sex subgroup.

only 1965. When only picking units falling in the mixed male and female sex subgroup were considered, Mexican and Puerto Rican workers had faster rates of picking than white pickers in both 1965 and 1966.[8] The Mexican and Puerto Rican units had significantly higher productivity than white units in 1965, but not in 1966. The picking rates of the Mexican and Puerto Rican workers in the mixed sex subgroup were not significantly different from those of all male pickers in either 1965 or 1966.

<u>Worker Unit Size</u>

Picking units made up of one person working alone had significantly higher productivity levels on the average than those containing two or more workers in 1965. Picking units containing one person also had faster average picking rates than groups in 1966, but the difference was not significant in that year.

The interaction effects of worker unit size with worker unit experience indicated that although pickers working alone had faster picking rates on the average than groups, the productivity of individual pickers differed depending upon the experience he had picking apples. In both 1965 and 1966 the productivity of a one-man unit with less than two years of experience was increased less than that of a one-man unit having two or more years of experience. This interaction term was not significant in either year, however. Individuals had higher productivity than groups in both 1965 and 1966 when only "experienced" units were compared. But when units having less than two

---

[8]Sufficient data was not available to permit the calculation of a coefficient for colored units in this sex subgroup.

Table 6. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Size Individual Worker

Model	Year		Variables				
					X_{16}		
(1)	1965	Coefficient			1.292		
		Standard Error			0.296		
	1966	Coefficient			0.184		
		Standard Error			1.117		
				X_{16}		$X_{16}X_{17}$	
(2)	1965	Coefficient		1.469		-0.480	
		Standard Error		0.347		0.292	
	1966	Coefficient		0.243		-0.552	
		Standard Error		1.136		0.752	
				X_{16} [b]		$X_{16}X_{16}$ *	
(3)	1965	Coefficient		omit		omit	
		Standard Error					
	1966	Coefficient		singular		omit	
		Standard Error					
				X_{16}		$X_{16}X_{20}$	
(4)	1965	Coefficient		1.495		-1.286	
		Standard Error		0.330		0.775	
	1966	Coefficient		2.419		1.972	
		Standard Error		1.840		2.904	
			$X_{21}X_{12}$		$X_{21}X_{13}$		$X_{21}X_{14}$ [b]
(5)	1965	Coefficient	0.339		1.499		omit
		Standard Error	0.519		0.367		
	1966	Coefficient	4.308		-0.245		singular
		Standard Error					
			$X_{21}X_{15}$		$X_{21}X_{16}$		$X_{21}X_{17}$ *
(6)	1965	Coefficient	1.262		1.194		omit
		Standard Error	0.344		0.610		
	1966	Coefficient	4.802		5.600		omit
		Standard Error	1.485		3.425		
			$X_{21}X_{18}$		$X_{21}X_{19}$		$X_{21}X_{20}$
(7)	1965	Coefficient	0.789		1.690		3.442
		Standard Error	0.520		0.297		0.589
	1966	Coefficient	-0.481		0.360		3.551
		Standard Error	1.442		0.748		2.460

Table 6. (cont'd.)

[*]Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

years apple picking experience were examined separately the relative picking rates of the two sizes of picking units were not the same in these two years. For inexperienced pickers, those working alone had higher productivity than those working in groups in 1965, but in 1966 this relationship was reversed. Regardless of the size of the worker unit, experienced pickers harvested more bushels of apples per hour in both years than inexperienced pickers working in a comparable sized unit. That is, when the productivity of only pickers working alone was examined, units with more than one year of experience had faster picking rates than those with one or fewer years of experience. The same was true for units containing two or more persons.

Model (4) indicated that pickers working in groups of two or more persons had lower picking rates than pickers working alone in both 1965 and 1966 when both sizes of units were in the same residency category regardless of whether resident or nonresident of Michigan. And nonresidents were found to out-perform Michigan residents in both years within a given picking unit size class for both size classes contained in this analysis. The interaction terms for worker unit size and worker unit residence had different regression coefficient signs in the two years included in this study, but neither of the coefficients was significant.

Pickers working alone who were less than 26 years old approached having significantly lower productivity levels than pickers 26-50 years old working alone in 1965.[9] In 1966, the productivity levels of pickers working alone in these two age groups were not significantly different from each other. In addition, the relative performance of these two groups in 1966 was reversed from what it was in 1965. Neither the young nor the middle-aged pickers working alone had picking rates in both years which were significantly different from those of the average unit made up of two or more persons. The data available did not permit the calculation of a coefficient for workers over 50 years old who worked alone.

Both male pickers and female pickers who worked alone had higher productivity levels in both 1965 and 1966 than the average picking unit containing more than one worker.[10] The male pickers working alone were the only ones having significantly higher picking rates in both years, however. The productivity rates of the male workers were not significantly different from those of females in either year when both types of units were made up of pickers working alone. Nor did one of these sex subclasses have a faster picking rate in both years when only pickers working alone were considered.

A consistent pattern was found in the performance of different ethnic subgroups when pickers working alone were separated from those

---

[9]The level of significance was 0.058.

[10]No coefficient could be calculated for a mixed male and female unit containing only one person since these two categories are mutually exclusive.

working in groups. Mexican and Puerto Rican pickers who worked alone had faster picking rates in both 1965 and 1966 than either colored or white pickers who also worked alone. White units had the lowest rates of the three ethnic subgroups in both of these years when only individual pickers were considered; while the colored units occupied a median position with respect to productivity in both years. The productivities of pickers working alone in the three ethnic subgroups were significantly different from each other in 1965, but not in 1966.

Worker Unit Experience

Picking units having less than two years of apple picking experience had lower productivity levels on the average in both 1965 and 1966 than those units having two or more years of experience. In 1965, the productivity of inexperienced workers was significantly lower than that of more experienced workers and in 1966 it approached being significantly lower.[11]

Less than two years of apple picking experience tended to lower productivity on the average for all types of picking units in both 1965 and 1966. And when an inexperienced picker worked alone, his productivity was reduced even more than that of two or more inexperienced pickers working together in 1965. The interaction effect of picking unit size and picking unit experience was not the same in 1966, however, as it was in 1965. In 1966, the productivity of inexperienced pickers working alone was not reduced as much as the productivity of

[11] In 1966 the picking rates for inexperienced and experienced workers were significantly different at the 0.065 level.

Table 7. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Experience Less Than Two Years

Model	Year		Variables				
					X_{17}		
(1)	1965	Coefficient			-2.093		
		Standard Error			0.148		
	1966	Coefficient			-0.517		
		Standard Error			0.284		
				X_{17}		$X_{17}X_{17}$*	
(2)	1965	Coefficient		-1.049		omit	
		Standard Error		1.402			
	1966	Coefficient		-4.706		omit	
		Standard Error		6.850			
				X_{17}		$X_{17}X_{16}$	
(3)	1965	Coefficient		-1.882		-0.334	
		Standard Error		0.248		0.305	
	1966	Coefficient		-0.843		0.687	
		Standard Error		0.492		0.618	
				X_{17}		$X_{17}X_{20}$	
(4)	1965	Coefficient		-2.309		1.483	
		Standard Error		0.163		0.435	
	1966	Coefficient		-0.580		1.238	
		Standard Error		0.307		0.912	
			$X_{22}X_{12}$		$X_{22}X_{13}$		$X_{22}X_{14}$
(5)	1965	Coefficient	-1.772		-2.478		0.415
		Standard Error	0.300		0.179		0.604
	1966	Coefficient	-0.058		-0.632		-0.113
		Standard Error	0.589		0.517		0.818
			$X_{22}X_{15}$		$X_{22}X_{16}$[b]		$X_{22}X_{17}$
(6)	1965	Coefficient	-2.202		omit		-2.054
		Standard Error	0.185				0.271
	1966	Coefficient	-0.289		singular		-0.908
		Standard Error	0.410				0.494
			$X_{22}X_{18}$		$X_{22}X_{19}$		$X_{22}X_{20}$[b]
(7)	1965	Coefficient	-2.420		-1.649		omit
		Standard Error	0.241		0.254		
	1966	Coefficient	-0.754		0.799		singular
		Standard Error	0.359		0.569		

Table 7. (cont'd.)

[*] Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

[b] "Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

two or more inexperienced pickers working together. However, the regression coefficient for this interaction term was not significant in either year. Regardless of whether inexperienced workers picked alone or in groups, they had lower picking rates in both years than experienced workers picking in the same size picking unit.

Either having a lack of experience or being a Michigan resident tended to reduce productivity in both 1965 and 1966. But the interaction of worker unit experience and worker unit residence showed that not all workers were affected to the same degree by these factors. The productivity of inexperienced workers who were Michigan residents was reduced less in both years than that of inexperienced workers who were not residents of Michigan. This interaction term was significant in 1965, but not in 1966. When only picking units which were not residents of Michigan were considered, those with two or more years of experience had the highest productivity levels in both years. One experience category was not associated with the highest level of productivity in both years for workers who were Michigan residents, however. Among units which came from Michigan, those with two or more years of apple picking experience had the fastest picking rates in 1965, but in 1966 it was those with less than two years of experience which had the fastest rates. Within a given experience category, nonresidents of Michigan out-produced Michigan residents in both years regardless of whether workers had two or more years of experience or whether they had less than two years of experience.

The picking rates of units having less than two years of experience picking apples were significantly different from each other in 1965 when the units were grouped on the basis of age. The three age categories used to group these worker units were: (1) less than 26 years old, (2) 26-50 years old, and (3) more than 50 years old. The picking rates of inexperienced workers in these three age categories were not significantly different from each other in 1966, however. When the performance of inexperienced pickers was examined, those in the middle-aged class displayed the lowest picking rates of the three age groups in both 1965 and 1966. No pattern could be established for the younger age group or the older age group in these two years with respect to their picking rates except they both had higher rates than the middle-aged workers in both years. None of the three age groups of inexperienced workers had a productivity level significantly different from that of the overall average of units having two or more years of experience in both 1965 and 1966.

Worker units with less than two years of experience in both the male and the mixed male and female sex subgroups had slower picking rates than the average unit with two or more years of experience in both 1965 and 1966. These two sex subgroups of inexperienced workers did not differ significantly from each other in either year with respect to picking rates. Nor did one of these subgroups perform better than the other in both years. No regression coefficient could be calculated for inexperienced female worker units because of insufficient data.

The performance of only white and colored picking units could be examined when workers with less than two years of experience were separated from those having more experience.[12] The regression analysis indicated that inexperienced white worker units had significantly slower picking rates in both 1965 and 1966 than those of inexperienced colored worker units. The white units with less than two years of experience had significantly lower productivity levels in both years than the average unit with two or more years of experience, but the inexperienced colored units did not.

Worker Unit Ethnic Origin

The ethnic origin of a particular picking unit was not a consistent predictor of worker productivity in the two years 1965 and 1966. In 1965 colored picking units had significantly lower productivity on the average than white units; while the average Mexican and Puerto Rican picking unit picked more bushels of apples per hour than the average white unit picked. But in 1966, it was the colored workers who had the fastest average picking rates of the three ethnic subgroups observed and the Mexican and Puerto Rican workers observed in this year had lower average picking rates than did white units. Neither the colored nor the Mexican and Puerto Rican workers had productivity levels significantly different from the productivity of white picking units in 1966.

When workers were separated into two subgroups on the basis of their apple picking experience in model (2), the relationship between

---

[12] The available data did not permit calculation of a coefficient for inexperienced Mexican and Puerto Rican units.

Table 8. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Ethnic Origin Colored Worker

Model	Year		Variables				
					X_{18}		
(1)	1965	Coefficient			-1.181		
		Standard Error			0.182		
	1966	Coefficient			1.174		
		Standard Error			1.223		
				X_{18}		$X_{18}X_{17}$	
(2)	1965	Coefficient		-1.619		1.206	
		Standard Error		0.224		0.394	
	1966	Coefficient		0.404		1.301	
		Standard Error		1.340		3.637	
				X_{18}		$X_{18}X_{16}$	
(3)	1965	Coefficient		-0.884		-0.224	
		Standard Error		0.339		0.385	
	1966	Coefficient		-0.665		1.429	
		Standard Error		3.572		3.836	
				X_{18}		$X_{18}X_{20}$[b]	
(4)	1965	Coefficient		-1.088		omit	
		Standard Error					
	1966	Coefficient		3.614		singular	
		Standard Error		1.366			
			$X_{19}X_{12}$		$X_{19}X_{13}$		$X_{19}X_{14}$
(5)	1965	Coefficient	-0.689		-1.347		-1.323
		Standard Error	0.439		0.218		0.560
	1966	Coefficient	-15.217		0.916		-4.940
		Standard Error	22.043		1.541		3.293
			$X_{19}X_{15}$		$X_{19}X_{16}$[b]		$X_{19}X_{17}$
(6)	1965	Coefficient	-1.249		omit		-0.551
		Standard Error	0.227				0.391
	1966	Coefficient	-0.703		singular		0.796
		Standard Error	1.638				3.701
			$X_{19}X_{18}$*		$X_{19}X_{19}$*		$X_{19}X_{20}$*
(7)	1965	Coefficient	omit		omit		omit
		Standard Error					
	1966	Coefficient	omit		omit		omit
		Standard Error					

Table 8. (cont'd.)

[a]Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

ethnic origin and productivity was unchanged from that observed in model (1). In 1965, Mexican and Puerto Rican pickers had the highest productivity levels among units having less than two years of experience picking apples. They were followed by white and colored picking units in order of productivity. The three ethnic origin subgroups had the same relative picking rates in 1965 when only workers having two or more years of experience were considered as they had when only inexperienced units were examined. However, in 1966 colored units had the fastest picking rates of the three ethnic subgroups regardless of whether experienced or inexperienced picking units were considered. The colored units were followed in order of their productivity levels by the white worker units and the Mexican and Puerto Rican worker units in both the experienced and inexperienced cases in 1966. Workers in all three ethnic subgroups who had more than one year of experience picking apples had higher productivity levels in both 1965 and 1966 than those having no more than one year of experience with only one exception. The exception was for colored pickers in 1965. In this case, the inexperienced workers out-picked the ones having two or more years of experience.

Colored workers were shown to have lower picking rates than white workers in both 1965 and 1966 by model (3). This result for

Table 9. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Ethnic Origin Mexican or Puerto Rican Worker

Model	Year		Variables		
				X_{19}	
(1)	1965	Coefficient		0.146	
		Standard Error		0.205	
	1966	Coefficient		-0.365	
		Standard Error		0.571	
			X_{19}		$X_{19}X_{17}$
(2)	1965	Coefficient	0.162		0.500
		Standard Error	0.279		0.416
	1966	Coefficient	-0.380		-1.419
		Standard Error	0.670		2.079
			X_{19}		$X_{19}X_{16}$
(3)	1965	Coefficient	0.084		0.443
		Standard Error	0.311		0.409
	1966	Coefficient	-0.297		2.256
		Standard Error	0.730		1.248
			X_{19}		$X_{19}X_{20}$
(4)	1965	Coefficient	0.485		-2.451
		Standard Error	0.216		0.939
	1966	Coefficient	1.250		5.855
		Standard Error	0.810		3.909
			$X_{20}X_{12}$	$X_{20}X_{13}$	$X_{20}X_{14}$
(5)	1965	Coefficient	0.811	0.118	-0.592
		Standard Error	0.422	0.252	0.790
	1966	Coefficient	-2.369	-0.542	-3.489
		Standard Error	2.177	0.970	2.141
			$X_{20}X_{15}$	$X_{20}X_{16}$ [b]	$X_{20}X_{17}$
(6)	1965	Coefficient	0.575	omit	0.406
		Standard Error	0.278		0.321
	1966	Coefficient	2.561	singular	-1.069
		Standard Error	1.157		0.789
			$X_{20}X_{18}$*	$X_{20}X_{19}$*	$X_{20}X_{20}$*
(7)	1965	Coefficient	omit	omit	omit
		Standard Error			
	1966	Coefficient	omit	omit	omit
		Standard Error			

Table 9. (cont'd.)

[a]Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

1966 did not agree with model (1), but the regression coefficient in model (3) for colored workers in 1966 cannot be viewed with much confidence due to its extremely high standard error. In 1965 the productivity of colored workers was reduced even more if they worked alone, but this was not true in 1966. In the latter year the productivity of colored workers was reduced less by working alone than if they worked in groups of two or more. The productivity of Mexican or Puerto Rican picking units was shown to be higher than that of white units by model (3) in 1965, but not in 1966. This result agrees with those of model (1). In 1965 the productivity of Mexican or Puerto Rican worker units was increased even more if these units were composed of individual pickers. The interaction of worker unit ethnic origin with unit size showed the picking rates of Mexican or Puerto Rican units to be reduced less in 1966 by pickers working alone as opposed to working in groups of two or more persons. Neither interaction term discussed above was significant in either 1965 or 1966.

Regardless of whether a picking unit was of white or Mexican and Puerto Rican ethnic origin, its productivity was higher in both 1965 and 1966 if its members were not residents of Michigan than if they were.[13] When only nonresidents of Michigan were considered, Mexican and Puerto Rican units had faster picking rates than white workers in both 1965 and 1966. This was not true in the case of Michigan residents, however, for in 1965 white pickers had higher productivity levels than pickers of Mexican and Puerto Rican ethnic origin when both were Michigan residents. The interaction term between worker unit ethnic origin and worker unit residence did not show the same interaction effect in 1965 and 1966 for these two variables in the case of Mexican and Puerto Rican units. In 1965, being both a nonresident of Michigan and of Mexican and Puerto Rican ethnic origin was associated with significantly greater increases in productivity than being a resident of Michigan and of Mexican and Puerto Rican ethnic origin. But in 1966 the combination of Michigan resident and Mexican and Puerto Rican ethnic origin was associated with greater productivity increases than was the nonresident - Mexican and Puerto Rican combination. This interaction effect was not significant in 1966, however.

The picking rates of colored workers in three different age classes: less than 26 years old, 26-50 years old, and over 50 years old, were not significantly different from each other in either 1965 or 1966. And the productivity of the colored workers in these three age groups varied so much from 1965 to 1966 that no one age group could be identified as the most productive or the least productive in

---

[13]No coefficient was calculated for the interaction of unit residence with unit ethnic origin in the case of colored workers because of insufficient data.

both of these years. Colored units in both the less than 26 year-old, and the over 50 year-old age groups had picking rates below that of the average white unit in both 1965 and 1966. The middle-aged colored unit had a productivity level below that of the average white unit in 1965, but not in 1966. When the productivity of workers in the same three age categories as above, but having Mexican and Puerto Rican ethnic background was examined, the different age groups were found to have picking rates which were not significantly different from each other in either 1965 or 1966. Among the Mexican and Puerto Rican workers, those over 50 years old had the slowest picking rates in both years. They were also the only age subgroup among this ethnic category to have lowering picking rates than the average white unit in both 1965 and 1966. The other two age subgroups of Mexican and Puerto Rican ethnic background had higher productivity than the average white unit in 1965 and lower productivity than the average white unit in 1966.

Two relationships were found to hold in both 1965 and 1966 in model (6) for the ethnic origin variable. Colored worker units containing both male and female pickers had higher productivity levels in both years than units made up of only male workers. And among Mexican and Puerto Rican units, those containing only male workers had the fastest picking rates in both 1965 and 1966.[14] The productivities of the colored pickers in the male units and the mixed male and female units did not differ significantly from each other in either year, while the productivities of the same two sex subgroups among Mexican

---

[14]Regression coefficients for colored female units and Mexican and Puerto Rican female units were not calculated due to insufficient data.

and Puerto Rican workers did differ significantly from each other in 1966. Male pickers of Spanish ethnic origin had significantly higher picking rates in both 1965 and 1966 then the average white unit.

Worker Unit Residence

Michigan residents had lower average picking rates than nonresidents of Michigan in both 1965 and 1966. But the average productivity of Michigan residents was significantly lower than that of nonresidents in only 1965.

The interaction effects of worker unit residence and worker unit apple picking experience in model (4) have been discussed previously.[15] This interaction variable was also included in model (2) and the interaction effects observed were the same as in model (4). The results of model (2) indicate that the productivity of Michigan residents having less than two years of experience is reduced less than the productivity of nonresidents of Michigan who have less than two years of experience. Or, viewed in another way, one could say that the effect of being a Michigan resident reduced the productivity of inexperienced workers less than it did the productivity of workers with more than one year of experience. As was the case in model (4), the coefficient for this interaction term was significant in 1965, but not in 1966. When the level of picking rates were compared for different subgroups of the total sample of workers, models (2) and (4) did not give the same results in all cases, however. Model (2) showed experienced nonresidents of Michigan to have higher picking rates than

---

[15]See the discussion of model (4) under the heading of Worker Unit Experience on page 56.

Table 10. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Worker Unit Residence Michigan Resident

Model	Year		Variables		
			X_{20}		
(1)	1965	Coefficient	-0.005		
		Standard Error	0.180		
	1966	Coefficient	-0.301		
		Standard Error	0.411		
			X_{20}	$X_{20}X_{17}$	
(2)	1965	Coefficient	-1.311	1.449	
		Standard Error	0.208	0.447	
	1966	Coefficient	-0.632	1.515	
		Standard Error	0.512	1.090	
			X_{20}	$X_{20}X_{16}$	
(3)	1965	Coefficient	0.262	-1.714	
		Standard Error	0.378	0.433	
	1966	Coefficient	-0.843	1.330	
		Standard Error	0.713	0.917	
			X_{20}	$X_{20}X_{20}$ *	
(4)	1965	Coefficient	-1.909	omit	
		Standard Error	1.790		
	1966	Coefficient	-14.834	omit	
		Standard Error	10.556		
			$X_{23}X_{12}$	$X_{23}X_{13}$	$X_{23}X_{14}$
(5)	1965	Coefficient	-0.765	-0.959	-1.186
		Standard Error	0.587	0.217	0.421
	1966	Coefficient	0.360	-0.588	0.236
		Standard Error	1.648	1.050	0.864
			$X_{23}X_{15}$	$X_{23}X_{16}$ [b]	$X_{23}X_{17}$
(6)	1965	Coefficient	-1.500	omit	0.250
		Standard Error	0.222		0.417
	1966	Coefficient	0.511	singular	-0.154
		Standard Error	0.576		0.786
			$X_{23}X_{18}$	$X_{23}X_{19}$	$X_{23}X_{20}$ [b]
(7)	1965	Coefficient	-1.423	-0.795	omit
		Standard Error	0.242	0.321	
	1966	Coefficient	0.559	0.523	singular
		Standard Error	0.589	1.169	

Table 10. (cont'd.)

*Where "omit" is indicated for a variable in both years for a model, the variable was excluded in formulating the model.

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

inexperienced nonresidents in both 1965 and 1966 as was the case in model (4). Models (2) and (4) also both indicated experienced nonresidents to have higher productivity than experienced Michigan residents in both years. But when the productivity levels of inexperienced workers having different places of residence were examined, the results obtained with model (2) were just the opposite of those indicated by model (4). Model (2) showed inexperienced nonresidents of Michigan to have lower picking rates in both years than inexperienced Michigan residents had. It also indicated that in 1965, inexperienced residents of Michigan had faster picking rates than Michigan residents with more than one year of experience and that in 1966 the experienced residents out-performed the inexperienced ones. Both of these results were contrary to those of model (4).

The interaction term of worker unit residence with worker unit size in model (3) did not give the same results in 1965 as it did in 1966. The productivity of Michigan residents working alone was increased less than that of residents working in groups in 1965. While in 1966 the productivity of Michigan residents working alone was reduced less than that of residents working in groups. Michigan residents working alone had lower picking rates than the average of all nonresident picking units in 1965, but in 1966, the residents working alone had faster rates than the average nonresident unit. The coefficient of the unit residence - unit size interaction term was significant in 1965, but not in 1966.

When the average productivity of all pickers less than 26 years old was compared to the average productivity of all workers 26-50 years old, the younger workers had lower picking rates in both 1965 and 1966. But when only Michigan residents were considered in model (5) pickers less than 26 years old had higher productivity levels than any other age group in both 1965 and 1966. This result does not agree with that of model (4).[16] The picking rates of Michigan residents in the three age classes used in this analysis were not significantly different from each other in either year for model (5), however. The relative picking rates of Michigan residents who were 26-50 years old and over 50 years old were not the same in both 1965 and 1966.

Regression coefficients for only two sex subgroups were calculated in model (6) for Michigan residents.[17] Among units which were

---

[16] See the discussion of worker unit residence under the heading of <u>Worker Unit Age</u> on page 38 of this chapter. Model (4) shows workers aged 26-50 to have the highest productivity of the three age subgroups among Michigan residents. In addition to being more consistent with the results of model (1), the results of model (4) seem to be more in accord with expectations. The middle-aged subgroup should have more maturity and experience than the younger workers and more physical capability than the older pickers. Model (5) does not separate out the influence of age on productivity as well as model (4) since nonresidents of all ages are grouped together in model (5). Therefore, model (4) would be expected to give a stronger explanation of the influence of age and residence on productivity.

[17] The available data did not permit the calculation of a coefficient for female Michigan residents.

from Michigan those containing only male pickers had significantly lower productivity levels in 1965 than those containing both male and female pickers. In 1966 the picking rates of the male units were faster than those of the mixed male and female units, but not significantly so. This outcome in model (6) was just the opposite of what was found in model (4). Part of the explanation for this inconsistent result between models (4) and (6) may be due to the accuracy with which the regression coefficient for the mixed male and female sex - Michigan resident variable in these two models was calculated. The standard error of this coefficient in both models was about twice as large as the coefficient itself in 1965. In 1966 the coefficient for this variable was estimated even less accurately.

Again, in model (7) only two regression coefficients were calculated for Michigan residents.[18] Both white and colored ethnic subgroups which were Michigan residents had slower picking rates than the average picking unit which was not from Michigan in 1965. But in 1966, Michigan residents in both of these ethnic subgroups had higher productivity levels than the average nonresident picking unit. This finding does not agree with the results of model (1) which showed Michigan residents to have lower average picking rates than nonresidents in 1966.[19] The white and colored picking units which were from

---

[18]Sufficient observations were not available for Mexican and Puerto Rican units to permit the calculation of a coefficient for this interaction effect.

[19]This result may have occurred because the coefficients for Michigan residents in the white and colored ethnic subgroups in model (7) were not estimated very accurately in 1966. The standard errors of the coefficients for both of these subgroups were larger than the coefficients themselves in that year.

Michigan did not have significantly different productivity levels in either 1965 or 1966. Nor did one of these ethnic subgroups have the fastest picking rate in both of these years.

Summary

The relationship of selected worker unit characteristics to the unit's productivity picking apples was discussed in this chapter. The age, sex, size, experience, ethnic origin, and residence of the unit were the characteristics considered. The effect on worker productivity of each of these characteristics individually as well as selected interaction effects were presented.

Apple pickers from 26 to 50 years old were more productive on the average than either younger or older pickers and units having two or more years of experience picking apples harvested more bushels per hour than less experienced ones. Considering only females, those over 50 were faster pickers than either of the two younger age groups. Being inexperienced tended to reduce the productivity of younger pickers less than it did the productivity of those 26-50 years of age. In fact, when only inexperienced pickers were considered those 26-50 years old had the lowest picking rates of the three age subgroups.

Male worker units were faster pickers on the average than either female worker units or mixed male and female units. But among workers less than 26 years old mixed male and female units picked more bushels of apples per hour than either male units or female units. Mixed male and female units also had higher picking rates than all-male units when only colored workers were considered; while females were the fastest pickers among workers over 50 years old.

Persons working alone tended to harvest more bushels of apples per hour than persons working in groups of two or more and residents of Michigan were less productive apple pickers than nonresidents on the average. But ethnic origin was not found to be consistently related to apple picking productivity when analyzed for the total sample of workers. Within certain subgroups of workers, however, some consistent relationships were found for the ethnic origin variable. Colored pickers out-performed either white pickers or Mexican and Puerto Rican pickers in the under 26 age group. While Mexican and Puerto Rican units were more productive than either of the other two ethnic subgroups among pickers working alone. In addition, Mexican and Puerto Rican picking units were faster than white picking units when only mixed male and female units were considered, when only inexperienced units were considered, and when only nonresidents of Michigan were considered.

CHAPTER V

RELATIONSHIP OF OPERATOR CONTROLLED VARIABLES TO WORKER PRODUCTIVITY

A discussion of the regression analysis results for those variables "under operator control" is presented in this chapter. The relationships found in 1965 and 1966 for models (1)-(7) will be discussed for the variables: type of picking, degree of tree pruning, type of market picked for, bonus paid, type of supervision, type of picking equipment, and tree height. The tables included in this chapter give regression coefficients and standard errors for only those variables under discussion.

Type of Picking

Preserving the stems on all apples picked seems to have the expected effect of reducing apple picking rates. This effect is expected since the stem must be grasped along with the apple during picking and, in addition, apples picked in this manner are sold as fresh fruit which requires greater care in handling to prevent bruising.

When workers were required to pick apples in such a manner that stems remained on all apples their productivity was lower on the average in both 1965 and 1966 than the productivity of workers picking apples without regard for stems. Workers picking apples with all stems on showed a significant difference in picking rates from other pickers in only 1965, however.

Table 11. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Type of Picking with Stems on

Model	Year		Variables		
			X_1		
(1)	1965	Coefficient	-0.806		
		Standard Error	0.202		
	1966	Coefficient	-1.696		
		Standard Error	1.666		
			X_1	X_1X_{17} [a]	
(2)	1965	Coefficient	-0.793	omit	
		Standard Error	0.204		
	1966	Coefficient	-1.294	no data	
		Standard Error	1.743		
			X_1	X_1X_{16} [a]	
(3)	1965	Coefficient	-0.794	omit	
		Standard Error	0.203		
	1966	Coefficient	-4.505	no data	
		Standard Error	2.965		
			X_1	X_1X_{20} [a]	
(4)	1965	Coefficient	-0.736	omit	
		Standard Error	0.203		
	1966	Coefficient	0.522	no data	
		Standard Error	1.879		
			X_1X_{12}	X_1X_{13}	X_1X_{14} [a]
(5)	1965	Coefficient	-0.604	-0.840	omit
		Standard Error	0.384	0.261	
	1966	Coefficient	-11.329	-2.388	no data
		Standard Error	20.671	2.388	
			X_1X_{15}	X_1X_{16} [a]	X_1X_{17}
(6)	1965	Coefficient	-0.863	omit	-1.116
		Standard Error	0.253		0.384
	1966	Coefficient	-1.724	no data	-5.431
		Standard Error	2.796		3.308
			X_1X_{18}	X_1X_{19} [a]	X_1X_{20} [b]
(7)	1965	Coefficient	0.022	omit	omit
		Standard Error	0.285		
	1966	Coefficient	-3.546	no data	singular
		Standard Error	2.652		

Table 11. (cont'd.)

[a]"No data" signifies that no observations were made for the variable in the year indicated. The variable was dropped from the model for both years.

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

The interaction of this variable with the experience, size, and residence of the picking units could not be examined because of the unavailability of data. Workers in both the age classes less than 26 years old and 26-50 years old had slower picking rates when all apples were picked with stems on than did the average worker who picked without regard to stems.[1] However, neither of these age groups had rates picking "stems on" which were significantly different from those of the average worker picking without regard for stems. The productivity levels of the young and middle-aged workers did not differ significantly from each other in either year when they were both picking all apples with the stems on. But, the relative productivity levels of the young and middle-aged workers picking "stems on" changed from 1965 to 1966.

The picking rates of male worker units and worker units containing both males and females did not differ significantly in either 1965 or 1966 when both types of work groups were picking all apples with the stems on. Both worker units containing only males and those containing both males and females had lower productivity levels in

---

[1]Observations on workers over 50 years old were not available.

both years when they were picking all apples with the stems on than did the average worker unit which did not have to preserve all stems. The relative productivity of male and mixed male and female worker units was the same in both years when both picked all apples with the stems on. Mixed units of males and females had lower picking rates than the all-male units in both 1965 and 1966.[2]

No comparison of worker units of different ethnic origin picking all apples with the stems on could be made because a regression coefficient could only be calculated for white workers in this case.

No clear evidence emerges from this analysis as to differences in the abilities of the various subclasses of workers studied under this picking condition with the exception of the all-male sex category. The all-male units did not display significantly different picking rates, however. The analysis of this variable was hampered by a lack of observations on several subclasses of workers.

Degree of Tree Pruning

The influence of tree pruning on the productivity of workers is difficult to predict. On the one hand, one would hypothesize that a well pruned tree should be easier to pick because of fewer obstacles to reaching the fruit. However, to the extent that a high degree of pruning is associated with an attempt to produce large, highly-colored fruit for the fresh market expected productivity might be lower.

The degree of tree pruning did not have a consistent influence on average worker productivity for the observations made in 1965 and

---

[2]No observations were available for female picking units in this situation.

1966. The signs of the regression coefficients for both A and B pruning were reversed in the two years for which model (1) was fitted. In 1965 the regression coefficient for A pruning was negative (compared to C pruning), while it was positive in the following year. The signs of the regression coefficients for B pruning were just the reverse of those for A pruning in the same two years. The coefficient for A pruning was not significant in either year, while B pruning had a significant influence on productivity in only 1965.

Only the interaction effects of A pruning with worker unit experience could be assessed in model (2). This interaction was not significant in either 1965 or 1966. But it showed that regardless of the experience, productivity was higher in C-pruned trees than in A-pruned trees in 1965 and the reverse was true in 1966. Experienced workers did have faster picking rates in both years than those with less than two years of experience when both types of workers picked in trees of the same degree of pruning regardless of whether it was A or C type.

The interaction effects of the degree of pruning with worker unit size could not be assessed for either A or B pruning because of insufficient data. The same was true for the interaction of pruning with worker unit residence.

The results of model (5) show that workers 26-50 years old picked more apples per hour than workers less than 26 years old in both 1965 and 1966 when both age groups worked in A-pruned trees. The same results occurred when both age groups worked in B-pruned trees.[3] The

---

[3]A regression coefficient could not be calculated for workers over 50 years old in trees of either A or B type pruning in both years.

Table 12. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Degree of Tree Pruning Well Pruned

Model	Year		Variables		
				X_3	
(1)	1965	Coefficient		-0.235	
		Standard Error		0.251	
	1966	Coefficient		0.731	
		Standard Error		1.413	
			X_3		X_3X_{17}
(2)	1965	Coefficient	-0.024		-0.121
		Standard Error	0.273		0.344
	1966	Coefficient	0.973		0.014
		Standard Error	1.445		2.842
			X_3		X_3X_{16}[b]
(3)	1965	Coefficient	-0.211		omit
		Standard Error			
	1966	Coefficient	-1.664		singular
		Standard Error	1.669		
			X_3		X_3X_{20}[b]
(4)	1965	Coefficient	-0.142		omit
		Standard Error	0.253		
	1966	Coefficient	0.399		singular
		Standard Error	1.417		
			X_3X_{12}	X_3X_{13}	X_3X_{14}[b]
(5)	1965	Coefficient	-0.758	0.077	omit
		Standard Error	0.523	0.308	
	1966	Coefficient	-29.970	1.131	singular
		Standard Error	22.160	1.818	
			X_3X_{15}	X_3X_{16}	X_3X_{17}
(6)	1965	Coefficient	-0.558	-0.165	0.053
		Standard Error	0.316	0.552	0.449
	1966	Coefficient	5.672	36.743	1.533
		Standard Error	6.448	18.367	2.280
			X_3X_{18}[b]	X_3X_{19}[b]	X_3X_{20}
(7)	1965	Coefficient	omit	omit	2.590
		Standard Error			0.690
	1966	Coefficient	singular	singular	-1.335
		Standard Error			2.997

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

Table 13. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Degree of Tree Pruning Some to Moderate Pruning

Model	Year		Variables		
				X_4	
(1)	1965	Coefficient		0.464	
		Standard Error		0.209	
	1966	Coefficient		-0.223	
		Standard Error		1.057	
			X_4	X_4X_{17}[b]	
(2)	1965	Coefficient	0.648	omit	
		Standard Error	0.209		
	1966	Coefficient	0.059	singular	
		Standard Error	1.095		
			X_4	X_4X_{16}[b]	
(3)	1965	Coefficient	0.525	omit	
		Standard Error	0.207		
	1966	Coefficient	-0.858	singular	
		Standard Error	1.195		
			X_4	X_4X_{20}[b]	
(4)	1965	Coefficient	0.636	omit	
		Standard Error	0.210		
	1966	Coefficient	1.149	singular	
		Standard Error	1.186		
			X_4X_{12}	X_4X_{13}	X_4X_{14}[b]
(5)	1965	Coefficient	0.274	0.722	omit
		Standard Error	0.441	0.252	
	1966	Coefficient	-25.412	-1.064	singular
		Standard Error	16.716	1.640	
			X_4X_{15}	X_4X_{16}[b]	X_4X_{17}
(6)	1965	Coefficient	0.485	omit	0.628
		Standard Error	0.258		0.388
	1966	Coefficient	8.556	singular	-2.413
		Standard Error	6.104		1.805
			X_4X_{18}	X_4X_{19}	X_4X_{20}
(7)	1965	Coefficient	-0.053	1.465	2.741
		Standard Error	0.214	0.281	0.647
	1966	Coefficient	-1.318	0.429	0.076
		Standard Error	1.529	2.958	3.801

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

productivity rates for the two age groups were not significantly different from each other under either type of tree pruning in either year, however. When only young pickers, less than 26 years old, are considered they picked more bushels of apples per hour in B-pruned trees than in A-pruned trees in both years. The 26-50 year old workers did not consistently perform at higher rates under one type of pruning in both years, however. Neither the young nor the middle-aged pickers had productivity levels in either A- or B-pruned trees which were significantly different from the average worker in trees of type C pruning in both 1965 and 1966.

The only consistent relationships in both years between type of pruning and worker unit sex in model (6) were that females picked more bushels of apples per hour than did males when both types of units worked in A-pruned trees and that males had higher picking rates in B-pruned trees than under pruning condition A. Female workers had higher productivity levels than males in both 1965 and 1966 when both sex groups worked in A-pruned trees. The performance of mixed male and female work units in trees pruned "A" was inconsistent. In 1965 their productivity was higher than either all-male units or all-female units. In 1966 the productivity of the mixed units was the lowest of the three groups working in A-pruned trees. The difference between the male, female, and mixed worker units picking A-pruned trees was not significant in either year. Male pickers had higher productivity levels when picking apples in B-pruned trees than in A-pruned trees in both 1965 and 1966. The productivity of mixed male and female units was higher under pruning condition B in 1965 than when picking A-pruned trees, but not in 1966. No comparison of this nature was possible for female pickers. In 1966 the productivity of male units was significantly higher at the 0.071 level than that of mixed male and female units when both worked in B-pruned trees, but the relative picking rates of these two units in 1966 in either A- or B-pruned trees was reversed from what it was in 1965. None of the three sex groups had picking rates in both years which were significantly different in either trees pruned "A" or "B" from that of the average picker in trees of type C pruning.

No comparison of working units of different ethnic origin was possible for well pruned trees since data were only sufficient under this pruning condition to calculate regression coefficients for Mexican and Puerto Rican workers in both years. In B-pruned trees, however, white pickers had the slowest picking rates of the three ethnic types in both 1965 and 1966. White pickers in B-pruned trees picked fewer bushels of apples per hour than did the average picker working in trees pruned type C in both years.[4] Colored worker units and Mexican and Puerto Rican worker units, while both having higher productivity levels than white picking units in both 1965 and 1966 in B-pruned trees, did not have the same relative productivity levels in both years. Colored picking units picked fewer apples per hour on the average under these conditions in 1965, and more apples per hour in 1966, than did Mexican and Puerto Rican units. In 1965 the productivity levels of the three ethnic origin groups picking B-pruned

---

[4]But the difference was not significant in either year.

trees were significantly different from each other, but not in 1966. Mexican and Puerto Rican picking units, the only group for which a comparison is possible, picked more apples per hour in B-pruned trees than in A-pruned trees in both 1965 and 1966. Although the picking rates of both colored and Mexican and Puerto Rican workers were higher in B-pruned trees than those of the average worker in trees of type C pruning in both years, they were significantly higher in only 1965.

There is no evidence in the above results to support the hypothesis that trees which are highly pruned increase worker productivity. To the extent that type A pruning is associated with apples picked for the fresh market one would expect to find females having higher productivity levels than males when picking fruit for this market since they had higher picking rates in A-pruned trees. The results above showing that all-male worker units and Mexican and Puerto Rican worker units had higher picking rates in B-pruned trees than in trees of A pruning supports the observation that a high degree of pruning may be associated with fruit being picked for the fresh market thereby reducing worker productivity.

Type of Market Picked For

Picking apples to be sold as fresh fruit would be expected to reduce worker productivity below that of picking apples to be processed because greater care must be exercised to prevent bruising and in fruit selection. The results of the statistical analysis of this study support the above expectation for on the average picking

Table 14. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Type of Market Picked For Retail

Model	Year		Variables		
			X_5		
(1)	1965	Coefficient	-0.938		
		Standard Error	0.185		
	1966	Coefficient	-4.500		
		Standard Error	0.978		
			X_5	X_5X_{17}[b]	
(2)	1965	Coefficient	-0.873	omit	
		Standard Error	0.188		
	1966	Coefficient	-4.654	singular	
		Standard Error	0.986		
			X_5	X_5X_{16}	
(3)	1965	Coefficient	-1.250	0.654	
		Standard Error	0.302	0.364	
	1966	Coefficient	-13.738	10.299	
		Standard Error	5.939	5.968	
			X_5	X_5X_{20}[b]	
(4)	1965	Coefficient	-0.863	omit	
		Standard Error	0.187		
	1966	Coefficient	-4.065	singular	
		Standard Error	0.982		
			X_5X_{12}	X_5X_{13}	X_5X_{14}[b]
(5)	1965	Coefficient	-0.777	-0.918	omit
		Standard Error	0.393	0.225	
	1966	Coefficient	-6.853	-3.408	singular
		Standard Error	2.452	1.168	
			X_5X_{15}	X_5X_{16}	X_5X_{17}[b]
(6)	1965	Coefficient	-0.516	-1.057	omit
		Standard Error	0.235	0.597	
	1966	Coefficient	-2.309	58.251	singular
		Standard Error	1.164	27.484	
			X_5X_{18}	X_5X_{19}[b]	X_5X_{20}[b]
(7)	1965	Coefficient	-0.581	omit	omit
		Standard Error	0.269		
	1966	Coefficient	-4.418	singular	singular
		Standard Error	0.987		

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

apples for the fresh market reduced worker productivity significantly below that for picking processing apples.[5]

The data available did not permit an examination of the interaction effects of either worker unit experience or residence with the type of market on which apples were to be sold. But the number of persons in a picking unit did have a significant relationship to the productivity of the unit when they picked apples for the retail market. Picking apples for sale as fresh fruit reduced the productivity of all worker units on the average in both years, but this reduction was less for individuals picking alone than for picking units of two or more persons.[6]

Models (5)-(7) produced only one relationship which was significant with respect to the market for which apples were being picked. The picking rates of young and middle-aged workers were not significantly different in either 1965 or 1966 when both picked apples for sale as fresh fruit and both had rates picking apples for this market which were significantly lower than the average worker picking processing apples in both of these years.[7] The relative productivity of the young and middle-aged workers was not the same in both years, however.

The productivity of males picking apples for the retail market was significantly less than that of females picking for the same

---

[5]Significant at less than .0005 level in both years.

[6]Significant at least at the 0.081 level in both years.

[7]Data did not permit the calculation of a coefficient for workers over 50 years old.

market in 1966. But in 1965 the productivities of these two groups picking apples for the retail market were not significantly different and the relative productivity of these two groups was reversed from what it was in 1966. Male workers picking apples for sale as fresh fruit had picking rates significantly lower than the average worker picking processing apples in both years. While females, when picking for the fresh market, had lower rates in 1965, and higher rates in 1966, than the average worker picking processing apples. This difference for females was significant only in 1966. Apparently, there was not a perfect correlation between trees being classed as A-pruned and their being picked for the fresh market. The analysis of this variables does not support the observation made earlier that all-female worker units might be expected to have higher productivity levels than all-male units when picking for the fresh market.

Sufficient data were available to permit the examination of only white workers picking apples for the fresh market. Therefore, the relative productivities of workers in other ethnic groups could not be compared. The white workers picked significantly fewer bushels of apples for the fresh market in both years than did the average picker working with processing apples.

Rate of Pay

Changes in the rate of payment per bushel of apples received by pickers were on the average negatively related to changes in productivity in both 1965 and 1966, but the regression coefficient for this variable was significantly different from zero only in 1965.

Table 15. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Rate of Pay

Model	Year		Variables				
					X_8		
(1)	1965	Coefficient			-0.174		
		Standard Error			0.025		
	1966	Coefficient			-2.137		
		Standard Error			5.420		
				X_8		X_8X_{17}	
(2)	1965	Coefficient		-0.163		-0.101	
		Standard Error		0.030		0.053	
	1966	Coefficient		-6.828		16.677	
		Standard Error		6.286		13.162	
				X_8		X_8X_{16}	
(3)	1965	Coefficient		-0.217		0.063	
		Standard Error		0.036		0.039	
	1966	Coefficient		20.572		-42.602	
		Standard Error		7.659		11.017	
				X_8		X_8X_{20}	
(4)	1965	Coefficient		-0.145		-0.128	
		Standard Error		0.030		0.054	
	1966	Coefficient		-0.659		7.297	
		Standard Error		5.592		34.038	
			X_8X_{12}		X_8X_{13}		X_8X_{14}
(5)	1965	Coefficient	-0.183		-0.173		-0.238
		Standard Error	0.046		0.029		0.053
	1966	Coefficient	2.035		-8.305		-4.994
		Standard Error	24.539		7.450		10.431
			X_8X_{15}		X_8X_{16} [b]		X_8X_{17}
(6)	1965	Coefficient	-0.517		omit		-0.265
		Standard Error	0.031				0.042
	1966	Coefficient	-24.311		singular		16.314
		Standard Error	8.222				7.950
			X_8X_{18}		X_8X_{19} [b]		X_8X_{20}
(7)	1965	Coefficient	-0.150		omit		-0.857
		Standard Error	0.028				0.113
	1966	Coefficient	-2.980		singular		8.425
		Standard Error	5.588				28.729

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

This result may have two possible explanations. First, growers commonly adjust the amount they offer workers for picking apples in accord with picking conditions. Growers with orchards which are difficult to pick must offer more per bushel in order to secure an adequate number of pickers. Second, the goal of pickers may be such that they desire some relatively fixed income level. Given this condition, pickers would be able to attain their income goals by reducing their picking rate if the rate of payment per bushel was raised.

Model (2) indicated that an increase in the rate of pay was associated with a decrease in worker productivity in both 1965 and 1966. In 1965 this relationship was significantly different from zero and the productivity of units with less than two years of experience picking apples was reduced more by an increase in pay rates than was the productivity of more experienced pickers.[8] The following year an increase in pay rates was not associated with a decrease in productivity which was significantly different from zero. And the picking rates of inexperienced worker units were not decreased as much by an increase in pay rates as were the rates of the experienced worker units. This interaction term was not significant in 1966.

The rate of pay variable did not have a consistent regression coefficient sign in model (3) for the two years analyzed. In 1965 the coefficient for this variable had a negative sign and it was significantly different from zero. The interaction of rate of pay with picking unit size showed that the productivity of individuals working alone tended to be decreased less by an increase in the rate

---

[8]This relationship approached being significant at the .05 level. It was significant at the .054 level.

of pay than was the productivity of pickers working in groups of two or more.[9] The coefficient for the rate of pay variable was positive in 1966 and it was also significantly different from zero. And in this year individuals working alone had smaller increases in productivity as pay rates were increased than did workers in groups of two or more.[10]

In model (4) the regression coefficients for the rate of pay-worker unit residence interaction terms for 1965 and 1966 differed in sign, but there was a negative relationship between rate of pay and worker unit productivity in both years for this model.[11] In 1965 the productivity of Michigan residents was decreased significantly more than was the productivity of nonresidents by an increase in pay rates. In 1966 Michigan residents' productivity was decreased less than that of nonresidents by a pay rate increase and this interaction term was not significant.

Model (5) indicates that an increase in the rate of pay tended to decrease the productivity of workers over 50 years old more than that of workers less than 26 years old in both 1965 and 1966. The relative influence of a change in pay rates was not consistent for the workers aged 26-50, however. In 1965 a one-unit increase in pay rates resulted in the smallest decrease in productivity for this

---

[9]The coefficient for the interaction term was significant at the .10 level in 1965.

[10]The interaction term coefficient in this year was significant at less than the .0005 level.

[11]In 1965 this relationship was significantly different from zero and in 1966 it was not.

group amont the three age subgroups; and in 1966 it resulted in the greatest decrease. The relationship was negative for all age groups in both years with the exception of the youngest workers in 1966. The effects of changes in pay rates on the productivity of the three age groups were not significantly different from each other in either 1965 or 1966. Nor were any of the changes in productivity resulting from a one-unit change in the rate of pay for a particular age group significantly different from zero in more than one year.

An increase in the pay rate was associated with a decrease in the picking rates of male units in both 1965 and 1966. But a change in the rate of pay was not associated with a consistent change for both years in the productivity of mixed male and female picking units. The changes in picking rates made by male and mixed male and female units in response to a given pay rate change were significantly different from each other in both years, however. And the changes in productivity resulting from a unit change in pay rates were significantly different from zero for both male and mixed male and female units in both years.[12]

Changes in the rate of payment per bushel of apples were associated with negative changes in productivity for white workers in both 1965 and 1966. The changes in the picking rates of Mexican and Puerto Rican workers in response to a pay rate change were not consistent in these two years, however. In 1965 the response of

---

[12]All-female units were not analyzed due to insufficient data.

these workers due to a change in pay rates was negative and in 1966 it was positive.[13] A given increase in pay rates decreased the productivity of Mexican and Puerto Rican pickers significantly more than that of white workers in 1965. The influence of a change in payment rates on productivity was not significantly different for these two types of picking units in 1966. Neither the white nor the Mexican and Puerto Rican workers had changes in picking rates significantly different from zero in both years in response to a one-unit change in pay rates.

The results of the statistical analysis of the rate of pay variable were not consistent. This may have been due in part to the relatively small number of observations for some of the worker unit subgroups in 1966.

Bonus Paid

The bonus payment as used by most fruit growers generally consists of a part of the total payment to workers being withheld until the end of a harvest season. As such, it is an incentive to pickers to remain in one location during the harvest thus minimizing the growers labor recruitment problems. Pickers receiving a bonus may realize higher earnings at the end of the harvest season than those receiving no bonus, but they probably forego some immediate compensation.

The relative productivities of the average workers receiving bonuses and those not receiving bonuses were not consistent for the

---

[13] The data did not permit the response of colored workers to be evaluated.

Table 16. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Bonus Paid No Bonus

Model	Year		Variables		
				X_9	
(1)	1965	Coefficient		0.478	
		Standard Error		0.214	
	1966	Coefficient		-1.253	
		Standard Error		1.159	
			X_9	X_9X_{17}	
(2)	1965	Coefficient	0.234	0.665	
		Standard Error	0.252	0.456	
	1966	Coefficient	-1.959	1.433	
		Standard Error	1.337	3.000	
			X_9	X_9X_{16} [b]	
(3)	1965	Coefficient	0.567	omit	
		Standard Error	0.216		
	1966	Coefficient	-0.146	singular	
		Standard Error	1.309		
			X_9	X_9X_{20}	
(4)	1965	Coefficient	0.221	1.561	
		Standard Error	0.243	0.409	
	1966	Coefficient	1.209	5.982	
		Standard Error	1.371	4.142	
			X_9X_{12}	X_9X_{13}	X_9X_{14}
(5)	1965	Coefficient	0.386	0.647	0.076
		Standard Error	0.424	0.278	0.548
	1966	Coefficient	-3.014	0.019	-7.100
		Standard Error	9.262	1.531	2.772
			X_9X_{15}	X_9X_{16} [b]	X_9X_{17}
(6)	1965	Coefficient	0.109	omit	0.899
		Standard Error	0.277		0.366
	1966	Coefficient	-1.174	singular	3.871
		Standard Error	1.443		2.559
			X_9X_{18}	X_9X_{19} [b]	X_9X_{20} [b]
(7)	1965	Coefficient	0.246	omit	omit
		Standard Error	0.236		
	1966	Coefficient	-2.864	singular	singular
		Standard Error	1.491		

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

two years 1965 and 1966. The average worker receiving a bonus had a lower picking rate than did those not receiving a bonus in 1965, but this relationship was reversed in 1966. Workers under these two alternative payment situations had significantly different picking rates only in 1965.

The interaction term between bonus payment and the experience of the worker had a consistent sign in both years. The regression coefficient for this variable was not significant in either year, however. The picking rates of inexperienced workers who did not receive a bonus were increased more in 1965, and decreased less in 1966, than were the rates of workers with more than one year of experience who did not receive a bonus. But workers with no more than one year of experience had lower productivity in both years than more experienced workers when both types of workers picked under the same bonus conditions regardless of whether they were paid a bonus or not. The use of a bonus payment did not affect pickers in the same way in both 1965 and 1966. In 1965 both the experienced workers and those with less than two years of experience picked more bushels of apples per hour when they received no bonus. The following year both types of pickers had faster picking rates when they were paid a bonus than when they received none.

The interaction effects of worker unit size with bonus payment could not be assessed because of insufficient data.

In model (4) the worker unit residence was used as an interaction term with the bonus payment variable and more consistent results for 1965 and 1966 were obtained. Workers who were residents of Michigan had higher productivity levels in both years when they received no bonus than when a bonus was paid. The same was true for nonresidents of Michigan. Regardless of whether pickers received a bonus or not, Michigan residents could not match the productivity of nonresidents in either year when both types of workers picked under the same bonus payment conditions. This was true even though Michigan residents had greater increases in their picking rates in both years than did nonresidents when both types of workers did not receive a bonus. The bonus payment-worker unit residence interaction effect was significant in only 1965.

The relative productivity of picking units in different age categories, receiving no bonus, was not changed from that of the average of all units in the sample. Of those units receiving no bonus payment, workers 26-50 years old had the highest picking rates in both 1965 and 1966 while those over 50 years old had the lowest in both years. The productivities of the workers in the three age groups were significantly different in only 1966 when no bonus was paid.[14] Of the age subgroups which received no bonus, none had significantly different performance in both years from the average of all workers paid a bonus.

The most interesting result of models (5) through (7) for this variable was that of the interaction between bonus payment and worker unit sex. Model (1) showed male workers to have higher productivity levels on the average than either females or mixed male and female units. But model (6) indicates that when workers receive no bonus

---

[14]These productivities differed at a level of 0.060 in 1966.

payment, the mixed male and female units had higher picking rates than male units.[15] The productivity of mixed male and female units was higher than that of male picking units in both years when neither type of unit received bonus payments.[16] When they did not receive a bonus neither the mixed nor the male picking units had picking rates significantly different in both years from the average of all units paid bonuses.

No comparison of the productivity of workers in different ethnic groups could be made when no bonus was paid because a regression coefficient could only be calculated for white workers under this condition in both years.

The nature of the bonus payment variable may help explain the observed interaction effects of no bonus payment with the inexperienced workers and with Michigan residents. The inexperienced picker may be spurred on by visions of getting rich quick when he receives his total compensation immediately. Many Michigan residents who harvest fruit do so on a part-time basis on week-ends or after work or school and may not plan to work for one grower during an entire harvest season. An explanation for the mixed male and female worker units having higher productivity than the male worker units when no bonus was paid is not readily apparent. One possible explanation of this empirical result is that the structure of the sample of workers in the "no bonus" category was such that most of the mixed worker units were nonresidents

---

[15] A coefficient was not calculated for worker units containing only females.

[16] The productivity levels of these two types of units were significantly different at the 0.082 level in 1965 and at the 0.083 level in 1966.

of Michigan while most of the males were Michigan residents. This seems reasonable since Mexican workers usually travel as family groups. In this situation the effect of being a nonresident may have outweighed the influence of being a male worker.

Type of Supervision

Close supervision did not have a consistent influence on the productivity of the average picking unit in 1965 and 1966. The signs of the regression coefficient for this variable were reversed for the two years in model (1). However, this coefficient was significant at least at the 0.07 level in both years.

The data available permitted the calculation of only one interaction coefficient in models (2) through (4). This was for the interaction between type of supervision and worker unit size for which the signs of the regression coefficient were reversed for the two years in which observations were made. The results indicated that when working under close supervision, the productivity of individual pickers was increased more than was the productivity of two or more pickers working together in 1965. But in 1966 the productivity of pickers working alone was increased less than that of groups of workers under these same conditions. As a result, pickers working alone under close supervision had higher productivity levels than the average unit under other types of supervision in 1965. But in 1966 the individual picker under close supervision had lower picking rates than the average worker under other types of supervision. This interaction term was significant in only 1965.

Table 17. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Type of Supervision Close

Model	Year		Variables		
			X_{10}		
(1)	1965	Coefficient	0.728		
		Standard Error	0.173		
	1966	Coefficient	-2.823		
		Standard Error	1.592		
			X_{10}	$X_{10}X_{17}$[b]	
(2)	1965	Coefficient	0.585	omit	
		Standard Error	0.173		
	1966	Coefficient	-3.059	singular	
		Standard Error	1.737		
			X_{10}	$X_{10}X_{16}$	
(3)	1965	Coefficient	0.003	0.939	
		Standard Error	0.280	0.342	
	1966	Coefficient	0.333	-0.946	
		Standard Error	2.221	1.372	
			X_{10}	$X_{10}X_{20}$[b]	
(4)	1965	Coefficient	0.568	omit	
		Standard Error	0.174		
	1966	Coefficient	1.205	singular	
		Standard Error	1.908		
			$X_{10}X_{12}$	$X_{10}X_{13}$	$X_{10}X_{14}$
(5)	1965	Coefficient	1.327	0.486	-0.353
		Standard Error	0.379	0.207	0.508
	1966	Coefficient	-4.202	-3.558	-6.274
		Standard Error	4.232	2.356	2.412
			$X_{10}X_{15}$	$X_{10}X_{16}$[b]	$X_{10}X_{17}$[b]
(6)	1965	Coefficient	0.997	omit	omit
		Standard Error	0.217		
	1966	Coefficient	0.254	singular	singular
		Standard Error	2.241		
			$X_{10}X_{18}$	$X_{10}X_{19}$[b]	$X_{10}X_{20}$
(7)	1965	Coefficient	0.062	omit	3.624
		Standard Error	0.240		0.532
	1966	Coefficient	-3.887	singular	-19.619
		Standard Error	1.922		14.468

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

Only workers over 50 years old had the same relative productivity in both 1965 and 1966 under close supervision. These workers had the lowest picking rates of the three age groups observed under close supervision in both years. The productivity of the older workers under this type of supervision was less than that of the average picking unit under other types of supervision in both years. The productivities of the three age groups under close supervision were significantly different from each other in 1965, but not in 1966. And none of the three age groups under close supervision had picking rates significantly different from the average of all workers under other types of supervision in both years.

All-male picking units working under close supervision had higher productivity levels in both 1965 and 1966 than the average unit under other types of supervision. This difference was significant in only 1965, however. Insufficient data made comparisons of male units with units from other sex groups impossible under close supervision.

The productivity of white workers was significantly less than that of Mexican and Puerto Rican workers when both worked under close supervision in 1965, but not in 1966.[17] In fact, the relative productivities of the white and the Mexican and Puerto Rican workers were reversed in 1966 from what they were in 1965. Neither the white nor the Mexican and Puerto Rican workers had picking rates under close supervision which differed significantly in both years from the average of all workers under other types of supervision.

---

[17]Sufficient data were not available for colored pickers working under this type of supervision to permit the calculation of a regression coefficient.

The lack of consistent relationships for this variable may have been in part due to the way in which this variable was measured. The determination of type of supervision was made subjectively by the enumerators in both years. This was further complicated by the fact that the same enumerators were not used in both 1965 and 1966. Analysis of this variable was also hampered by a limited number of observations on workers under rather close supervision.

Type of Picking Equipment

Worker picking units which used metal picking containers had higher productivity levels on the average than those using canvas or other types of picking containers in both 1965 and 1966. The picking rates of those using metal containers were significantly higher in only 1965, however.

The interaction effect of metal picking containers with pickers having under two years of experience was not the same in both 1965 and 1966. In 1965, the use of metal equipment tended to increase productivity more for inexperienced pickers than for those having more than one year of experience picking apples. But the productivity of inexperienced workers was increased less than that of experienced workers by the use of metal picking containers in 1966. This interaction effect was significant in only 1966. When all workers were experienced, those using metal containers had higher productivity levels in both years. But the highest picking rate was not associated with one type of picking container in both years when only workers with less than two years of experience were considered. Of those pickers using one particular type of container, those with more than one year of experience had

Table 18. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Type of Picking Equipment Metal

Model	Year		Variables				
					X_{11}		
(1)	1965	Coefficient			1.343		
		Standard Error			0.318		
	1966	Coefficient			0.440		
		Standard Error			0.515		
				X_{11}		$X_{11}X_{17}$	
(2)	1965	Coefficient		1.186		0.348	
		Standard Error		0.367		0.728	
	1966	Coefficient		1.348		-2.967	
		Standard Error		0.675		1.148	
				X_{11}		$X_{11}X_{16}$	
(3)	1965	Coefficient		1.497		-0.339	
		Standard Error		0.624		0.696	
	1966	Coefficient		-1.439		2.396	
		Standard Error		0.984		1.159	
				X_{11}		$X_{11}X_{20}$	
(4)	1965	Coefficient		1.116		1.661	
		Standard Error		0.358		0.844	
	1966	Coefficient		0.252		0.760	
		Standard Error		0.608		1.783	
			$X_{11}X_{12}$		$X_{11}X_{13}$		$X_{11}X_{14}$
(5)	1965	Coefficient	1.198		1.320		-0.559
		Standard Error	0.944		0.383		0.880
	1966	Coefficient	-0.817		-0.205		1.271
		Standard Error	1.390		0.926		0.951
			$X_{11}X_{15}$		$X_{11}X_{16}$		$X_{11}X_{17}$
(6)	1965	Coefficient	1.112		-5.280		1.281
		Standard Error	0.377		1.308		0.692
	1966	Coefficient	1.135		0.212		-1.399
		Standard Error	0.688		1.385		0.978
			$X_{11}X_{18}$		$X_{11}X_{19}$		$X_{11}X_{20}$
(7)	1965	Coefficient	0.721		1.568		4.735
		Standard Error	0.485		0.495		2.889
	1966	Coefficient	0.481		-1.669		-18.975
		Standard Error	0.543		1.750		17.406

the highest productivity levels in both years regardless of the type of picking container considered.

Pickers working alone and using metal picking containers had faster picking rates than the average of all picking units using other types of equipment in both 1965 and 1966. The use of metal equipment did not influence picking units consisting of only one person in the same manner in both years, however. Using this type of container tended to increase the picking rates of individuals less than it did the rates of units containing two or more persons in 1965. And in 1966 the use of metal containers by individuals decreased their productivity less than did the use of these containers by two or more persons picking together.

Michigan residents using metal picking equipment had faster picking rates in both 1965 and 1966 than residents using canvas bags or other types of equipment. Pickers who were not residents of Michigan also had higher productivity levels using metal equipment in both years. The use of metal picking containers tended to increase the productivity of Michigan residents more than that of nonresidents in both years. However, when using the same type of equipment, regardless of the type, Michigan residents picked fewer apples per hour than did nonresidents of Michigan in both 1965 and 1966.

Middle-aged workers had higher picking rates than young workers in both 1965 and 1966 when both age groups used metal picking equipment as opposed to other types. The influence of this type of equipment on older workers was not consistent in these two years, however. These workers had the fastest picking rates in 1965, and the slowest rates in 1966, when using metal containers. The average picking rates of the three age groups were not significantly different in either year when each group worked with metal picking equipment. Nor was the average productivity of any age group using metal containers significantly different in both years from the average picking rate of all workers using other types of equipment.

The relative picking rates of male workers and female workers using metal containers were the same in both 1965 and 1966. The males picked more apples per hour in both years. Males also picked more apples per hour using metal equipment than the average worker using other types of equipment in both years, but the difference was significant in only 1965. Mixed male and female picking units did not perform consistently in the two years observed when they used metal containers. In 1965 the mixed units had the highest picking rates using these containers, and in 1966 they had the lowest of the three sex groups. The average productivity levels of the male, female, and mixed picking units using metal containers were significantly different in 1965, but not in 1966.

White pickers using metal picking equipment picked more bushels of apples per hour in both 1965 and 1966 than did the average picker using other types of equipment. But the picking rates of the white workers using metal equipment did not differ significantly from the average worker using other equipment in either year, however. Workers of the other two ethnic backgrounds did not behave in this manner when using metal containers. In 1965 Mexican and Puerto Rican workers had the highest productivity levels using metal containers, but in 1966 their rates were lowest. Although white workers had higher picking rates when using metal containers than the average worker using other equipment, they had the lowest rate of the three ethnic groups using metal containers in 1965. While in 1966 they had the highest rate of the three groups using metal containers. Colored pickers maintained a median picking rate in both years when using metal equipment. The average picking rates of the three ethnic groups did not differ significantly in either year when they all used the metal picking containers.

Tree Height

The productivity of workers picking apples in trees over 18 feet tall would be expected to be lower than that of workers in shorter trees since a higher percentage of picking in the taller trees must be done from ladders. The effect of tree height on the average worker's productivity picking apples in 1965 was not consistent with its effect in 1966. The regression coefficients for this variable were not significant in either year, however. Working in trees over 18 feet tall tended to reduce picking rates below what they were in trees 14-18 feet tall in 1965. But in 1966 picking rates tended to be higher in the taller trees.

The interaction term in model (2) of tree height with picking unit experience was significant only in 1965. But its sign was positive in both 1965 and 1966 indicating that productivity was decreased less in 1965 and increased more in 1966 when working in tall trees if pickers had less than two years of apple picking experience than it would have been if pickers had over one year of experience. This analysis indicated that those workers with less than two years of experience had higher picking rates in tall trees than in shorter ones in both 1965 and 1966. But more experienced workers did not have higher productivity

Table 19. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Tree Height Over 18 Feet

Model	Year		Variables				
					X_{22}		
(1)	1965	Coefficient			-0.182		
		Standard Error			0.185		
	1966	Coefficient			0.263		
		Standard Error			1.188		
				X_{22}		$X_{22}X_{17}$	
(2)	1965	Coefficient		-0.307		0.702	
		Standard Error		0.225		0.373	
	1966	Coefficient		0.157		0.645	
		Standard Error		1.352		3.356	
				X_{22}		$X_{22}X_{16}$	
(3)	1965	Coefficient		-0.236		0.107	
		Standard Error		0.299		0.368	
	1966	Coefficient		-3.100		4.085	
		Standard Error		3.319		3.599	
				X_{22}		$X_{22}X_{20}$	
(4)	1965	Coefficient		-0.052		-0.353	
		Standard Error		0.197		0.496	
	1966	Coefficient		2.968		-8.391	
		Standard Error		1.400		3.227	
			$X_{25}X_{12}$		$X_{25}X_{13}$		$X_{25}X_{14}$
(5)	1965	Coefficient	0.756		-0.308		-0.958
		Standard Error	0.387		0.228		0.502
	1966	Coefficient	-15.581		-0.325		-4.696
		Standard Error	18.367		1.563		3.208
			$X_{25}X_{15}$		$X_{25}X_{16}$		$X_{25}X_{17}$
(6)	1965	Coefficient	-0.234		-0.610		0.223
		Standard Error	0.239		0.554		0.321
	1966	Coefficient	-0.078		212.887		-2.138
		Standard Error	1.585		88.004		3.350
			$X_{25}X_{18}$		$X_{25}X_{19}$ [b]		$X_{25}X_{20}$
(7)	1965	Coefficient	-2.115		omit		1.963
		Standard Error	2.276				2.265
	1966	Coefficient	-1.946		singular		0.990
		Standard Error	1.491				4.934

[b] "Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

levels in trees in one particular height range in both years. When the performance of experienced pickers was compared with that of workers having no more than one year of experience, and both types of workers were picking in trees of comparable heights, the more experienced pickers had higher productivity levels in both years regardless of whether they worked in short or tall trees. The relative picking rates of inexperienced workers in "tall" and "short" trees was not what was expected a priori. This outcome might have occurred for more than one reason. It is possible that picking in tall trees gives the inexperienced worker some psychological stimulus not present when he works from the ground. In effect, he has not learned that taller trees are harder to pick. It is also possible that apple yields were not the same for trees in the two height categories studied. Higher apple yields in the taller trees picked by the inexperienced workers could have more than offset the expected disadvantage from picking in taller trees. Apple yield was only indirectly reflected through the fruit size variable in the regression models used in this study.

Model (3) indicated that the productivity of picking units made up of one person was decreased less in both 1965 and 1966 by working in tall trees than was the productivity of units consisting of two or more workers. But this interaction term was not significant in either year. Pickers working alone had higher picking rates in trees 19 or more feet tall than did the average picking unit working in trees 14-18 feet tall in 1966, but not in 1965.

Residents of Michigan had their picking rates decreased more in 1965 and increased less in 1966 than did residents of other states by working in trees over 18 feet tall compared to trees 14-18 feet high.

This interaction variable in Model (4) was significant in only 1966. This model indicated that residents of Michigan picked more bushels of apples in short trees than in tall ones in both years. But that nonresidents had faster picking rates in the short trees in 1965 and in the tall trees in 1966. Michigan residents did not match the performance of nonresidents in either year in either tree height category.

Working in trees over 18 feet tall reduced the productivity level of both middle-aged workers and those over 50 years old below the average of all workers in trees 14-18 feet tall in both 1965 and 1966. And the picking rate of workers over 50 years old was less than that of middle-aged pickers in both years when both age groups were working in tall trees. Workers under 26 years old were not affected in the same way in these two years by working in tall trees. In 1965 young workers had the highest productivity level of the three age groups when all worked in tall trees. But in 1966 the young pickers had the lowest picking rate in these trees. Workers in the three age groups had significantly different average picking rates when working in tall trees in 1965, but not in 1966. And none of the age groups had a picking rate in tall trees which was significantly different from the average rate of all pickers in trees 14-18 feet tall.

Mexican and Puerto Rican workers were faster pickers in tall trees in both 1965 and 1966 than were white pickers in trees of the same height.[18] But the picking rates for these two types of workers were not significantly different in either year when both types worked

---

[18]Date were not available to permit an analysis of colored worker units.

in the tall trees. Neither the white nor the Mexican and Puerto Rican pickers had a productivity level in tall trees significantly different from that of the average worker picking in trees 14-18 feet tall in either 1965 or 1966.

The observed effect of picking in tall trees tending to depress picking rates of Michigan residents more than those of non-residents may be explained by nonresidents having a more professional status as fruit pickers and being more experienced handling ladders and working in trees. The fact that Mexican-Puerto Rican worker units were found in this analysis to have faster picking rates than white units in trees over 18 feet tall tends to support the above "professional status" explanation.

Summary

The relationship of seven variables under the control of the operator to worker productivity in apple harvesting was presented in this chapter. Type of picking, degree of tree pruning, type of market picked for, bonus paid, type of supervision, type of picking equipment, and tree height were the variables considered. The effect of each of these variables individually on worker productivity was presented along with selected interaction effects with worker unit characteristics.

Picking apples in such a manner that the stems remained on all apples reduced worker productivity below what it was when apples were picked without regard for stems.

A consistent relationship between the degree of tree pruning and worker productivity could not be established for the overall sample of workers. But when only workers less than 26 years old were considered, when only male workers were considered, or when only Mexican and Puerto Rican workers were considered they picked more bushels of apples per hour in moderately pruned trees than in well pruned trees. When well pruned trees were being picked by all workers, female units were more productive than male units. White worker units were the least productive of the three ethnic subgroups when only moderately pruned trees were being picked.

Worker units picking apples for sale as fresh fruit had lower productivity than units picking processing apples on the average. And picking apples for the fresh market did not reduce the productivity of individual workers as much as it did the productivity of two or more workers picking together.

Apple picking productivity was negatively related for the average picker to the rate of payment he received for each bushel of apples picked. And the productivity of workers over 50 years old was reduced more by an increase in payment rates than was the productivity of pickers under 26.

A consistent relationship was not found for the over-all sample of workers between the practice of paying bonuses to workers and their apple picking speed. But both Michigan residents and nonresidents of Michigan, when analyzed separately, had faster picking rates when they received no bonus payment; with the productivity of Michigan residents being increased more by the practice of making no bonus payment than was the productivity of nonresidents. Even though all-male worker units had the highest productivity level of the three sex subgroups on the average, when no bonus payment was made the mixed male and female sex subgroup picked more bushels of apples per hour than the all-male subgroup.

Close supervision of workers did not have a consistent influence on the productivity of the average picking unit in this analysis.

Workers using metal picking containers had higher productivity levels on the average than those using other types of containers. And the use of metal picking containers tended to increase productivity of Michigan residents more than that of nonresidents.

The relative productivity of workers picking tall and short trees was not found to be consistent in this study for the total sample of workers. But when only workers with less than two years of experience were considered they picked more bushels of apples per hour in tall trees than in short ones. The productivity of pickers working alone was decreased less by working in tall trees than was the productivity of units containing two or more workers. And when only Michigan residents were considered, they picked more bushels of apples per hour in short trees than in taller ones. Although on the average over-all conditions one ethnic subgroup was not found to be the most productive, Mexican and Puerto Rican workers were faster pickers than white workers when only tall trees were being picked.

CHAPTER VI

RELATIONSHIP OF VARIABLES NOT CONTROLLED BY OPERATOR TO WORKER PRODUCTIVITY

An analysis of those variables classed as not being directly controlled by the farm operator is presented in this chapter. In the order they are considered, the variables are: tree age, topography of orchard, weather conditions, tree spread, and fruit size. The table accompanying the discussion of each of these variables gives the regression coefficients and standard errors obtained in regression models (1)-(7) for the variables under discussion. Both the years 1965 and 1966 will be considered in presenting the results of the regression analyses.

Tree Age

As apple trees mature they grow taller and their spread becomes greater. This would be expected to make picking more difficult since longer ladders would be needed in addition to more ladder movement in older trees. The results support the above expectation for the most part. There was a negative relationship for the average worker between his productivity and the age of the trees he was picking in both 1965 and 1966. That is, picking rates tended to decline as tree age increased. The change in productivity associated with a unit change in tree age was significantly different from zero in only 1965, however.

When the influence of tree age on workers having different amounts of apple picking experience was examined, tree age was found

Table 20. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Tree Age

Model	Year		Variables				
					X_2		
(1)	1965	Coefficient			-0.046		
		Standard Error			0.005		
	1966	Coefficient			-0.059		
		Standard Error			0.037		
				X_2		X_2X_{17}	
(2)	1965	Coefficient		-0.039		-0.024	
		Standard Error		0.006		0.013	
	1966	Coefficient		-0.086		0.199	
		Standard Error		0.042		0.103	
				X_2		X_2X_{16}	
(3)	1965	Coefficient		-0.053		0.014	
		Standard Error		0.010		0.012	
	1966	Coefficient		0.055		-0.064	
		Standard Error		0.062		0.079	
				X_2		X_2X_{20}	
(4)	1965	Coefficient		-0.050		0.022	
		Standard Error		0.006		0.019	
	1966	Coefficient		0.006		-0.022	
		Standard Error		0.045		0.108	
			X_2X_{12}		X_2X_{13}		X_2X_{14}
(5)	1965	Coefficient	-0.060		-0.045		-0.028
		Standard Error	0.010		0.007		0.020
	1966	Coefficient	0.376		-0.131		0.030
		Standard Error	0.604		0.064		0.087
			X_2X_{15}		X_2X_{16}		X_2X_{17}
(6)	1965	Coefficient	-0.038		-0.026		-0.049
		Standard Error	0.007		0.018		0.012
	1966	Coefficient	0.045		8.100		-0.020
		Standard Error	0.057		3.425		0.098
			X_2X_{18}		X_2X_{19}		X_2X_{20}[b]
(7)	1965	Coefficient	-0.047		-0.006		omit
		Standard Error	0.007		0.010		
	1966	Coefficient	-0.044		-0.392		singular
		Standard Error	0.044		0.112		

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

to be negatively associated with productivity in both 1965 and 1966 for workers having more than one year of experience. The influence of tree age on productivity was significantly different from zero in both years for these workers. But the effect of tree age on workers having no more than one year of experience was not consistent between years. In 1965 there was a negative relationship between tree age and productivity for the inexperienced worker, while in 1966 this relationship was positive. In addition, the interaction term for tree age and worker unit experience suggests that the productivity of inexperienced pickers was decreased more in 1965, and decreased less in 1966, by an increase in tree age than was the productivity of more experienced pickers. The difference in the influence of tree age on productivity for the experienced and the inexperienced workers approached being significant in both years.[1]

The effect of an increase in tree age on picking rates was not the same in both 1965 and 1966 for picking units consisting of two or more persons. There was a negative relationship between changes in tree age and changes in productivity for these units in 1965, but in 1966 this relationship was positive. Productivity changes resulting from changes in tree age were significantly different from zero in only 1965, however, for picking units containing two or more persons. There was a negative relationship between changes in tree age and changes in picking rates in both years for units consisting of only one person. The influence of tree age on productivity was not

---

[1]In 1965 the difference was significant at the 0.070 level and in 1966 it was significant at the 0.052 level.

significantly different in either year for these two sizes of picking units even though the direction of the influence was not the same in 1966. An increase in tree age tended to decrease productivity less for persons working alone than it did for units containing two or more persons in 1965, but in 1966 an increase in tree age tended to increase productivity less for individual pickers than for persons working in groups.

A negative relationship existed between changes in tree age and changes in worker productivity for residents of Michigan in both 1965 and 1966. But residents of other states exhibited a negative relationship between productivity and changes in tree age in 1965, while in 1966 this relationship was positive. The influence of a change in tree age on picking rates was significantly different from zero in only 1965 for nonresidents of Michigan, however. An increase in tree age tended to decrease the productivity of Michigan residents less than that of nonresidents in 1965, while in 1966 an increase in tree age tended to increase Michigan residents' productivity less than it did that of nonresidents. The influence of tree age on the productivity of Michigan residents was not significantly different from that on nonresidents in either year.

The effect of a change in tree age on the productivity of workers 26-50 years old was significantly different from zero in both 1965 and 1966. This was not true for either the younger or the older age groups observed in this study. An increase in tree age was associated with a decrease in the picking rates of workers 26-50 years old in both 1965 and 1966. Both the younger and the older workers displayed a negative relationship between changes in tree age and changes in productivity in 1965 and a positive relationship between these variables in 1966. A given increase in tree age decreased the productivity of middle-aged workers more than that of older workers in both years. For the younger workers, however, the same increase in tree age was associated with the largest decrease in productivity of the three age groups in 1965 and the largest increase in productivity in 1966. The influence of tree age on picking rates did not differ significantly for the three age groups in either 1965 or 1966.

When males and females worked together in the same picking unit an increase in tree age tended to reduce productivity in both 1965 and 1966. The effect of an increase in tree age on productivity for the mixed units was significantly different from zero in only 1965, however. The productivity of both the all-male and the all-female units was affected differently in 1965 than it was in 1966 by a change in tree age. A negative relationship existed between changes in tree age and productivity for both these types of units in 1965, but in 1966 this relationship was positive for both units. The influence of a change in tree age on productivity was significantly different from zero only in 1965 for the male units and only in 1966 for the female units. The influence of a change in tree age on the productivity of workers in the three sex subgroups approached being significantly different from each other in 1966, but not in 1965.[2]

There was a negative relationship for both white and colored pickers between changes in tree age and productivity in both 1965

---

[2]These influences were significantly different at the 0.053 level in 1966.

and 1966.[3] But the relative influence on productivity of a change in tree age was not the same for pickers of these two ethnic groups in these two years. In 1965 a given change in tree age reduced the productivity of white units more than that of colored ones. But in 1966 the same change in tree age reduced the productivity of colored workers the most. Even though the above was true, the influence of a change in the age of trees on the productivity of white pickers was significantly different from what it was on the productivity of colored workers in both years. The influence of a change in tree age on productivity was not significantly different from zero in both years for either the white or the colored pickers.

Topography of Orchard

The productivity of pickers working in extremely hilly or rough orchards would be expected to be less than what it would be if they worked in level to gently rolling orchards because of the difficulty of moving ladders and other equipment from one location in the orchard to another. On the average picking units working in orchards having a level to gently rolling topography picked more bushels of apples per hour in both 1965 and 1966 than did units picking orchards which were hilly. The difference in the picking rates of units working under these two topographical conditions was not significant in either year, however.

The interactions of topography with worker unit experience, size, and residence could not be determined because of insufficient data.

---

[3]This relationship could not be assessed for Mexican and Puerto Rican workers because of singularity problems.

Table 21. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Topography of Orchard Level to Gently Rolling

Model	Year		Variables		
				X_6	
(1)	1965	Coefficient		0.743	
		Standard Error		0.647	
	1966	Coefficient		0.675	
		Standard Error		1.191	
			X_6		X_6X_{17}[b]
(2)	1965	Coefficient	0.058		omit
		Standard Error	0.689		
	1966	Coefficient	1.282		singular
		Standard Error	1.243		
			X_6		X_6X_{16}[b]
(3)	1965	Coefficient	1.081		omit
		Standard Error	0.657		
	1966	Coefficient	-1.289		singular
		Standard Error	1.318		
			X_6		X_6X_{20}[b]
(4)	1965	Coefficient	0.372		singular
		Standard Error	0.662		
	1966	Coefficient	0.006		omit
		Standard Error	1.251		
			X_6X_{12}[b]	X_6X_{13}	X_6X_{14}[b]
(5)	1965	Coefficient	omit	0.386	omit
		Standard Error		0.646	
	1966	Coefficient	singular	1.100	singular
		Standard Error		1.451	
			X_6X_{15}[b]	X_6X_{16}[b]	X_6X_{17}
(6)	1965	Coefficient	omit	omit	-0.264
		Standard Error			1.340
	1966	Coefficient	singular	singular	-1.648
		Standard Error			1.379
			X_6X_{18}	X_6X_{19}[b]	X_6X_{20}[b]
(7)	1965	Coefficient	0.959	omit	omit
		Standard Error	0.684		
	1966	Coefficient	0.099	singular	singular
		Standard Error	1.347		

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

The coefficient for workers 26-50 years old in model (5) was the only one calculated.[4] It indicated that workers in this age group had faster picking rates in leveler orchards than did the average picker in orchards classed as hilly in both 1965 and 1966, but the difference in rates was not significant in either of these years.

In model (6) sufficient data were available to calculate only one coefficient. This was for mixed male and female picking units which showed units of this type picking in level to gently rolling orchards to have lower productivity levels in both years then the average of all pickers in hilly orchards. The picking rates of the mixed male and female units in this case were not significantly lower in either year, however.

Sufficient data were available to calculate only one coefficient in model (7), also. White pickers working in orchards having no steep hills had higher, but not significantly so, productivity levels than the average of all workers in hilly orchards in both 1965 and 1966.

A lack of observations on pickers working in orchards classes as "hilly" made statistical analysis of the topography variable almost impossible except from the standpoint of the average worker unit. Sufficient data were not available to permit statistical analysis of various worker unit subgroups for this variable.

---

[4]No comparison between workers in different age subgroups could be made because of insufficient data.

<u>Weather Conditions</u>

Good weather conditions were hypothesized a priori to be the most favorable for high performance by pickers. In this category both high and low temperature extremes were excluded, wind velocity was low, and there was no precipitation. The results of the statistical analysis of the weather variable did not support the above hypothesis. Good weather was found to be associated with lower picking rates in both 1965 and 1966 for the average worker than were other types of weather. In addition, picking rates for the average worker in good weather were significantly different in both years from rates during other weather conditions.

Pickers had higher productivity levels in bad weather than in good weather in both 1965 and 1966 regardless of whether they had less than two years of apple picking experience or whether they had two or more years experience. Experienced pickers had faster picking rates on the average in both years than did those with no more than one year of apple picking experience when both types of pickers worked under the same weather conditions regardless of the type. The interaction effect of weather conditions with worker unit experience did not have the same sign in both years. In 1965, the productivity of inexperienced workers under good weather conditions was reduced less than was that of more experienced pickers in the same type weather. A year later the data showed the productivity of inexperienced workers to be reduced more in good weather than was the productivity of pickers having two or more years of experience. The regression coefficient for this interaction term was not significant in either year, however.

Table 22. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Weather Conditions Good

Model	Year		Variables				
					X_7		
(1)	1965	Coefficient			-0.719		
		Standard Error			0.128		
	1966	Coefficient			-0.719		
		Standard Error			0.271		
				X_7		X_7X_{17}	
(2)	1965	Coefficient		-0.890		0.348	
		Standard Error		0.162		0.263	
	1966	Coefficient		-0.405		-0.720	
		Standard Error		0.340		0.558	
				X_7		X_7X_{16}	
(3)	1965	Coefficient		-0.829		0.112	
		Standard Error		0.224		0.271	
	1966	Coefficient		-0.275		-0.623	
		Standard Error		0.429		0.542	
				X_7		X_7X_{20}	
(4)	1965	Coefficient		-0.816		0.044	
		Standard Error		0.141		0.341	
	1966	Coefficient		-0.822		1.080	
		Standard Error		0.283		1.021	
			X_7X_{12}		X_7X_{13}		X_7X_{14}
(5)	1965	Coefficient	-0.321		-0.960		-0.521
		Standard Error	0.275		0.156		0.399
	1966	Coefficient	-0.732		-0.986		0.242
		Standard Error	0.558		0.385		0.535
			X_7X_{15}		X_7X_{16}		X_7X_{17}
(6)	1965	Coefficient	-0.767		-0.211		-0.763
		Standard Error	0.159		0.488		0.245
	1966	Coefficient	-0.830		-0.976		-0.348
		Standard Error	0.353		1.107		0.428
			X_7X_{18}		X_7X_{19}		X_7X_{20}
(7)	1965	Coefficient	-0.431		-0.686		-0.447
		Standard Error	0.193		0.238		0.281
	1966	Coefficient	-0.312		-1.714		-0.597
		Standard Error	0.324		0.573		1.514

Good weather was associated with lower productivity on the average for all pickers in both 1965 and 1966 than was bad weather in model (3). The productivity of pickers working alone was reduced less in 1965 than was that of worker units consisting of two or more persons when both sizes of picking units worked in good weather. But in 1966 the productivity of individuals was reduced more in good weather than was the picking rate of larger sized picking units. The picking rates of different sized picking units were not significantly different from each other in either year, however, when both worked in good weather. Although individuals were shown in model (1) to have higher productivity levels on the average than larger sized picker units, in good weather individuals had lower picking rates than the average of all picking units working in bad weather.

Michigan residents had lower productivity levels than residents of other states in both 1965 and 1966 regardless of whether they worked in good or bad weather. The productivity of Michigan residents was reduced less than that of nonresidents by good weather, however, in both years. But the performance of Michigan residents was not significantly different from that of nonresidents in good weather in either year. When the productivity of nonresidents of Michigan under the two weather categories was compared, picking rates were higher in bad weather than in good weather in both years. But Michigan residents did not perform consistently better under one type of weather in the two years. In 1965 their picking rates were higher in bad weather, while in 1966 their performance was better in good weather.

Model (1) indicated that workers aged 26-50 years old had higher picking rates on the average in both 1965 and 1966 than either younger or older workers. But in both years pickers 26-50 years old had the lowest productivity levels of the three age groups when all workers were picking in good weather. The picking rates of this middle-aged group in good weather were significantly less than those of the average worker in bad weather in both 1965 and 1966. Neither the younger nor the older workers had picking rates significantly different in good weather from the average worker in bad weather in either year. The picking rates of the three age groups did not differ significantly from each other in either year, however, when all three worked in good weather. The relative productivities of the younger and older workers in good weather were not the same in 1965 as in 1966.

Mixed male and female picking units had higher productivity levels than all-male units in both 1965 and 1966 when both types of units picked in good weather. This differs from what was found to be true on the average for all conditions; in which case male units had the highest productivity of the three types of picking units based on sex. The productivity of female units was inconsistent in these two years relative to that of the other two sex subgroups. In 1965 female picking units had the highest productivity in good weather, while in 1966 their productivity was the lowest of the three sex subgroups in this weather. Male picking units working in good weather had significantly lower picking rates in both years than the average worker in bad weather. Neither the female nor the mixed male and female units, although having lower productivity in both years in good weather, had picking rates significantly different in good weather from that of the average worker under bad weather conditions in both years. The picking rates of the three sex subgroups in good weather did not differ significantly from each other in either 1965 or 1966.

All three ethnic groups observed in this study had lower picking rates under good weather conditions than the average of all pickers under the other weather condition in both 1965 and 1966. But only colored workers had significantly lower picking rates in both years in good weather than the average worker under other conditions. These workers had the lowest productivity rates of the three ethnic types in both years in good weather. White workers picked more bushels of apples per hour in good weather than either of the other two ethnic groups, while Mexican and Puerto Rican pickers held a median position with respect to productivity under these weather conditions in both years. The picking rates of the three ethnic subgroups did not differ significantly from each other in either year when they all worked in good weather.[5]

There may be two possible explanations for the unexpected empirical results of the analysis of the weather variable. First, the determination of what constitutes "good" weather was made by Michigan residents who were white. They may not have been aware of what was considered "good" weather by nonresident members of other ethnic groups. This explanation tends to be supported by the empirical results showing the productivity of Michigan residents to be reduced less in both years by good weather than was the productivity of nonresidents. It is also supported by the finding that white picking units had faster picking rates in both years than either of the other two ethnic

[5]In 1966 the average picking rates of these three subgroups did differ at the 0.105 level, however.

subgroups when all subgroups were working under good weather conditions. This was not found to be true on the average over-all conditions. Another possible explanation may be that the sample of workers observed under what were believed to be less favorable weather conditions was not the same as the sample observed under more favorable conditions. Those worker units observed under bad weather conditions may have been only one segment of all workers observed--those who were regular pickers with this activity as their sole means of support. The part-time workers may have chosen not to pick under disagreeable weather conditions. This may have also been true of women and children in migrant worker units. Under this explanation the weather variable would not have a direct influence on the performance of a given individual, but would determine the make-up of the sample of workers observed under different weather conditions.

Tree Spread

A negative relationship would be expected between worker unit picking rates and tree spread since increases in tree spread are associated with increases in tree height and tree age. The proportion of ladder time required in picking increases with tree height and more movement of ladders around trees is required as tree spread increases. The analysis of this variable showed the productivity of the average worker to be negatively related to the spread, or diameter of the bearing surface, of the trees being picked in both 1965 and 1966. The change in worker unit picking rates associated with a unit change in tree spread was significantly different from zero in only 1965, however.

Table 23. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Tree Spread

Model	Year		Variables		
			X_{21}		
(1)	1965	Coefficient	-0.006		
		Standard Error	0.003		
	1966	Coefficient	-0.107		
		Standard Error	0.097		
			X_{21}	$X_{21}X_{17}$	
(2)	1965	Coefficient	-0.010	0.005	
		Standard Error	0.007	0.008	
	1966	Coefficient	-0.075	-0.305	
		Standard Error	0.116	0.237	
			X_{21}	$X_{21}X_{16}$	
(3)	1965	Coefficient	-0.008	0.001	
		Standard Error	0.021	0.021	
	1966	Coefficient	-0.114	-0.090	
		Standard Error	0.196	0.232	
			X_{21}	$X_{21}X_{20}$	
(4)	1965	Coefficient	-0.007	0.057	
		Standard Error	0.003	0.037	
	1966	Coefficient	-0.288	0.442	
		Standard Error	0.126	0.263	
			$X_{24}X_{12}$	$X_{24}X_{13}$	$X_{24}X_{14}$
(5)	1965	Coefficient	-0.007	-0.007	0.042
		Standard Error	0.008	0.003	0.045
	1966	Coefficient	0.973	-0.020	-0.028
		Standard Error	0.901	0.160	0.201
			$X_{24}X_{15}$	$X_{24}X_{16}$	$X_{24}X_{17}$
(6)	1965	Coefficient	-0.008	-0.005	-0.005
		Standard Error	0.003	0.005	0.023
	1966	Coefficient	-0.237	-16.246	-0.102
		Standard Error	0.136	6.868	0.209
			$X_{24}X_{18}$[b]	$X_{24}X_{19}$[b]	$X_{24}X_{20}$
(7)	1965	Coefficient	singular	omit	-0.006
		Standard Error			0.003
	1966	Coefficient	omit	singular	-0.046
		Standard Error			0.715

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

The interaction term of tree spread with worker unit experience showed that the relationship between tree spread and productivity for workers with less than two years of experience was not significantly different from this relationship for pickers with two or more years of experience. The signs of the coefficients for this term in the two years 1965 and 1966 were reversed and neither coefficient was significant.

The sign of the regression coefficient for the interaction term between tree spread and unit size was positive one year and negative the next.[6] The effect of tree spread on the productivity of an individual working alone was not significantly different from this effect on pickers working in groups of two or more in either 1965 or 1966.

The influence of tree spread on the productivity of Michigan residents was not as great as it was on nonresidents of Michigan. There was a tendency in both years for the productivity of Michigan residents to be reduced less by a given increase in tree spread than was the productivity of nonresidents by the same increase in tree spread.[7]

The influences of tree spread on productivity for the three age groups examined in this study were not significantly different from each other in either 1965 or 1966. The 26-50 year old age group was the only one of the three groups which showed a consistent sign for the regression coefficient for both years. Productivity was negatively

---

[6]This coefficient was not significant in either year.

[7]The coefficient for this interaction term was significant at less than or equal to the 0.12 level in both years.

related to tree spread in both years for this group, but the effect of tree spread on productivity was significantly different from zero in only 1965. The signs of the regression coefficients for both the younger and the older age groups were reversed in the two years observed, but both of these groups had coefficients which did not differ significantly from zero in either year.

Worker unit picking rates were negatively related to tree spread in both 1965 and 1966 for male, female, and mixed male and female units. A given change in tree spread had the smallest influence on the productivity of the mixed units in both years. The effect of tree spread on productivity was not significantly different from zero in either year for this group. Male picking units did display changes in productivity which approached being significantly different from zero in both years as a result of changes in tree spread.[8] The effects of tree spread on productivity for the three sex subgroups approached being significantly different from each other in 1966, but not in 1965.[9]

A regression coefficient for the tree spread variable in model (7) was calculated for only one ethnic origin subgroup.[10] A negative relationship existed between picking rates and tree spread for Mexican and Puerto Rican units in both 1965 and 1966. The effect of tree

---

[8] In 1965 the tree spread coefficient was significantly different from zero at the 0.025 level for this group and in 1966 the significance level was 0.078.

[9] The tree spread coefficients for these three subgroups were significantly different at the 0.057 level in 1966.

[10] The data available did not permit the calculation of coefficients for the white and colored subgroups.

spread on productivity was not significantly different from zero in either year for these workers.

No significant differences in the productivity of workers in different subgroups emerged from the analysis of the tree spread variable. Michigan residents did, however, tend to show less of a reduction in picking rates than did nonresidents to a given increase in tree spread.

Fruit Size

Fruit size would be expected to influence apple picking speed, measured in bushels picked per hour, since more hand and arm movements would be required in picking a bushel of small apples compared to movements required in picking larger apples. Thus, picking speed would be expected to decrease as apple size decreases. Model (1) indicated that the average worker picked fewer bushels of apples per hour in both 1965 and 1966 when picking smaller apples numbering at least 176 per bushel than when picking apples numbering from 126 to 175 per bushel. The difference in the average worker's productivities when picking apples in these two size classes was significant in only 1966.

In 1965, the productivity of pickers with less than two years of experience picking apples was decreased more than that of more experienced pickers by working in trees producing small apples. However, in 1966 the productivity of the less experienced pickers was reduced less by picking small apples than was the productivity of units having two or more years of experience. The picking rates of the experienced and inexperienced workers were not significantly

Table 24. Regression Coefficients and Standard Errors for Models (1)-(7), 1965 and 1966, Fruit Size Over 175 Apples Per Bushel

Model	Year		Variables				
					X_{23}		
(1)	1965	Coefficient			-0.138		
		Standard Error			0.157		
	1966	Coefficient			-2.369		
		Standard Error			0.363		
				X_{23}		$X_{23}X_{17}$	
(2)	1965	Coefficient		-0.081		-0.398	
		Standard Error		0.184		0.303	
	1966	Coefficient		-2.704		1.057	
		Standard Error		0.446		0.763	
				X_{23}		$X_{23}X_{16}$	
(3)	1965	Coefficient		0.371		-0.831	
		Standard Error		0.253		0.306	
	1966	Coefficient		-3.685		2.003	
		Standard Error		0.633		0.765	
				X_{23}		$X_{23}X_{20}$	
(4)	1965	Coefficient		-0.242		0.538	
		Standard Error		0.171		0.368	
	1966	Coefficient		-2.286		1.921	
		Standard Error		0.364		3.067	
			$X_{26}X_{12}$		$X_{26}X_{13}$		$X_{26}X_{14}$
(5)	1965	Coefficient	0.061		-0.274		0.036
		Standard Error	0.340		0.189		0.419
	1966	Coefficient	-1.857		-1.811		-3.803
		Standard Error	0.671		0.533		0.752
			$X_{26}X_{15}$		$X_{26}X_{16}$		$X_{26}X_{17}$
(6)	1965	Coefficient	-0.433		0.059		0.334
		Standard Error	0.195		0.529		0.270
	1966	Coefficient	-1.789		-1.016		-3.677
		Standard Error	0.450		1.408		0.634
			$X_{26}X_{18}$		$X_{26}X_{19}$		$X_{26}X_{20}$[b]
(7)	1965	Coefficient	4.662		-4.852		omit
		Standard Error	1.308		1.329		
	1966	Coefficient	-2.623		-1.353		singular
		Standard Error	0.417		0.732		

[b]"Singular" indicates that the variable resulted in a singular matrix in the solution for regression coefficients in the year indicated. The variable was dropped from the model for both years.

different in either year, however, when both types of units picked apples numbering more than 175 per bushel. And experienced units picked more bushels of apples per hour in both years than did units having less than two years of experience when both types of units were picking apples in the same size class regardless of whether they were large or small. Model (1) also indicated that regardless of which experience category a worker unit belonged to, it picked more bushels of apples per hour when working with larger apples.

The size of the picking unit had differing effects on productivity in 1965 and 1966 when workers were picking apples numbering more than 175 per bushel. The productivity of units consisting of only one person was increased less in 1965, and decreased less in 1966, by picking small apples than was the productivity of units containing more than one person. Even though units of these two sizes differed in the above manner in these two years, the difference between their picking rates when working with small apples was significant in both years. Model (1) indicated that individual pickers on the average had higher productivity in both 1965 and 1966 than units of two or more persons. But individuals picking small apples had lower picking rates in both years than the average of all workers picking larger apples.

Picking small apples, those numbering more than 175 per bushel, reduced the productivity of Michigan residents less than that of nonresidents of Michigan in both 1965 and 1966. But Michigan residents and nonresidents did not have significantly different picking rates in either year when both types of units picked small apples. Nonresidents did, however, have higher productivity levels than Michigan residents in both years when both types of workers picked apples in the same size class regardless of whether they were large or small. Nonresidents picked more bushels of apples per hour in both 1965 and 1966 when they were picking apples numbering 125-175 per bushel than they did when picking smaller apples. But this was not the case with Michigan residents. In 1965 residents picked more bushels of apples per hour when the apples were classed as small than they did when picking large apples, while in 1966 the reverse was true.

Young workers had higher productivity levels than workers over 50 years old in both 1965 and 1966 when both age groups picked small apples. The productivity of middle-aged workers relative to that of the other two age groups was not consistent in these two years, however. In 1965 workers 26-50 years old had the lowest productivity of the three age groups when all types of workers picked small apples, but in 1966 these middle-aged workers had the fastest picking rates in this situation. The average productivity levels of the three age groups when they all picked small apples were not significantly different from each other in either year.[11] In 1966 each of the three age groups had picking rates significantly lower when picking small apples than the average of all workers picking apples numbering 125-175 per bushel. But in 1965 none of these subgroups had a picking rate for small apples significantly different from that of the average worker for larger apples.

---

[11]In 1966 these levels did approach being significantly different at the 0.05 level. They were significantly different at the 0.073 level.

The picking rates of male, female, and mixed male and female worker units were significantly different in 1966 when all three types picked small apples and in 1965 these rates approached being significantly different at the 0.05 level in this situation.[12] Only the male units and female units had productivity levels which were consistent relative to each other in both years, however. When workers were picking small apples numbering more than 175 per bushel, female worker units had faster picking rates than male units in both years. The performance of the mixed male and female units was not consistent in these two years relative to that of the other two types of units when small apples were being picked by all workers. Mixed units had the highest productivity in 1965, and the lowest in 1966, in this situation. When male units picked small apples their productivity was significantly lower in both years than that of the average unit picking larger apples. Female units picking small apples did not differ significantly in productivity from the average unit picking larger apples in either year.

Coefficients for only two ethnic groups were calculated for the case in which small apples were being picked.[13] White pickers had productivity levels significantly different from those of colored workers in 1965, but not in 1966, when both types were picking small apples. The performance of white pickers relative to that of colored pickers was not the same in both years, however, in this situation.

---

[12]These units had productivity levels significantly different at the 0.064 level in 1965 when picking small apples.

[13]The data available did not permit the calculation of a coefficient for Mexican and Puerto Rican workers in this situation.

In 1965 white pickers had faster rates than colored workers when both types of units picked small apples, but in 1966 this relationship was reversed. The sign of the regression coefficient for white units picking small apples was not the same in 1966 as it was in 1965. But in both years these workers in this situation had picking rates significantly different from those of the average unit picking larger apples. Colored units had rates lower in both years than those of the average picker working with large apples, when they picked smaller ones, and in 1965 their rates were significantly lower.[14]

The analysis of the fruit size variable produced two types of worker unit subgroup categories which showed significant differences between worker subgroups. Pickers working alone had significantly faster picking rates than units consisting of two or more pickers in both 1965 and 1966 when small apples were being picked by units of both sizes. There does not seem to be any apparent reason for the above result stemming directly from worker unit size. However, the background of the pickers working alone may have been different with respect to age, sex, experience, and other factors which do display some relationship to productivity. There may have been some tendency for families to work as units. To the extent that this is true one would expect the units containing two or more workers to be younger and less experienced on the average due to the presence of children. Both age and experience are shown in this study to have an effect on productivity. The other significant difference between subgroups of

---

[14]The rates of the colored units approached being significantly lower in both years, but in 1966 they differed only at the 0.062 level.

workers appeared with respect to worker unit sex. The result showing female units to have higher productivity levels than male units when both types of units were picking small apples can probably be explained by females having more nimble fingers and more experience at close, fine work such as sewing. One other consistent difference with respect to productivity was present between worker unit subgroups in the analysis of the fruit size variable, but a statistically significant result was not found. Workers less than 26 years old picked more bushels of apples per hour than workers over 50 years old in both 1965 and 1966 when both age subgroups were picking small apples. The quickness of the younger workers compared to older ones may explain this result.

Summary

The relationship of tree age, topography of orchard, weather conditions, tree spread, and fruit size to worker productivity picking apples was discussed in this chapter. These five variables were classed as not being directly controlled by the farm operator. They were analyzed both individually and in interaction terms with worker unit characteristics.

A negative relationship was found on the average between the age of a tree being picked and the productivity of workers harvesting apples. A given increase in tree age decreased the productivity of middle-aged workers more than it decreased the productivity of older workers.

Pickers working in hilly orchards harvested fewer bushels of apples per hour than did pickers working in level to gently rolling ones on the average.

Contrary to expectations, the productivity of the average picker in good weather was lower than his productivity in bad weather. This relationship held regardless of whether workers had less than two years of experience or whether they were more experienced. The productivity of Michigan residents was reduced less by working in good weather than was the productivity of nonresidents working under the same weather conditions. And pickers 26-50 years old had slower picking rates than either of the other two age subgroups when all pickers were working under good weather conditions, even though they were the most productive of the three subgroups on the average. The relative productivity of the three sex subgroups in good weather also differed from that found on the average. Mixed male and female units were faster pickers in good weather than all-male units. In good weather white workers picked more bushels of apples per hour than either of the other two ethnic subgroups; while colored workers were the least productive ethnic group in this situation.

Apple picking productivity was negatively related to the spread of trees being picked for the average worker. The reduction in the picking rates of Michigan residents caused by a given increase in tree spread was less than the reduction in the rates of nonresidents. And mixed male and female units suffered the smallest decrease in picking speed among the three sex subgroups as a result of a given increase in tree spread.

A positive relationship existed between the size of apples being picked and worker productivity for the average picker, i.e., more bushels of apples were picked per hour when picking large apples than when picking small ones. The productivity of pickers working alone was higher than that of pickers working in groups when only small apples were being picked. And the productivity of Michigan residents was reduced less by picking small apples than was the productivity of nonresidents. In contrast to the average picking rates of male worker units and female worker units over-all situations, female units were more productive than male units when only small apples were being picked.

CHAPTER VII

PRODUCTIVITY DIFFERENCES BY WORKER UNIT SUBCLASSES

A discussion of the empirical relationships found between selected variables and the productivity of workers picking apples on a piece-rate system was presented in Chapters IV, V and VI on a variable-by variable basis. This chapter summarizes the results of the regression analyses of worker productivity on a model-by-model basis. A detailed analysis of each variable included in the seven regression models used will not be repeated here. Rather, a discussion of the number and types of variables which were significantly related to worker productivity or showed a consistent relationship to productivity in both 1965 and 1966 will be presented in this chapter. Particular attention will be given to the results of the subgroup analyses utilized in this study which were designed to identify differential rates of productivity among selected subgroups of workers in the picking situations observed. The subgroups analyzed in this study were set up on the basis of the experience, size, residence, age, sex, and ethnic origin of the worker units for which data were collected.

Model (1)

The regression coefficients estimated for model (1) in both 1965 and 1966, and the standard errors of these coefficients, are presented in Table 25. This model did not contain any interaction terms so no inferences can be drawn about differing relationships between worker

Table 25. Regression Coefficients and Standard Errors, Model (1), 1965 and 1966

Variable	1965 Regression Coefficient	1965 Standard Error	1966 Regression Coefficient	1966 Standard Error
Constant	14.845	1.046	23.031	3.485
X_1	-0.086	.202	-1.696	1.666
X_2	-0.046	.005	-0.059	.037
X_3	-0.235	.251	.731	1.413
X_4	.464	.209	-0.223	1.057
X_5	-0.938	.185	-4.500	.978
X_6	.743	.647	.675	1.191
X_7	-0.719	.128	-0.719	.271
X_8	-0.174	.025	-2.137	5.420
X_9	.478	.214	-1.253	1.159
X_{10}	.728	.173	-2.823	1.592
X_{11}	1.343	.318	.440	.515
X_{12}	-0.424	.162	-1.290	.296
X_{13}	-2.007	.218	-1.621	.302
X_{14}	-1.651	.253	-1.276	.572
X_{15}	-1.281	.317	-1.402	1.147
X_{16}	1.292	.296	.184	1.117
X_{17}	-2.093	.148	-0.517	.284
X_{18}	-1.181	.182	1.174	1.223
X_{19}	.146	.205	-0.365	.571
X_{20}	-1.005	.180	-0.301	.411
X_{21}	-0.006	.003	-0.107	.097
X_{22}	-0.182	.185	.263	1.188
X_{23}	-0.138	.157	-2.369	.363

unit productivity and the independent variables of model (1) for worker unit subclasses. A picture of the types of variables which show a significant and/or consistent relationship to picking unit productivity in the two years studied can be obtained, however.

The independent variables in model (1) explained only about 19 percent of the variation in apple picking rates of worker units observed in 1965.[1] In 1966 about 25 percent of this variation was explained by the independent variables in model (1).[2] Although the amount of variation in apple picking rates explained by model (1) was relatively low in both 1965 and 1966, several variables did display a consistent relationship to worker productivity in both years. The signs of the regression coefficients for 16 of 23 independent variables in model (1) were consistent in the two years studied. Seven of the variables which displayed consistent regression coefficient signs were in the category of "people" variables. An additional five of these variables were designated as "not controlled by operator." The remaining four variables showing consistent signs were assumed to be "controlled by operator." The direction of the influence of an independent variable on worker productivity was questionable in seven of the above 16 cases. In these seven cases the standard error of the coefficient was larger than the coefficient itself in at least one of the two years for which this model was fitted. A fair degree of confidence may be placed in the direction of the influence of the

---

[1] R, the multiple correlation coefficient, was 0.4368 for model (1) in 1965.

[2] In 1966 the coefficient of multiple correlation, R, was 0.4990 for model (1).

independent variables on productivity for the remaining nine variables because their regression coefficients were larger than the associated standard errors in both years for model (1).

Only one of the nine variables which had regression coefficients of the same sign in both years, and for which the standard errors of the coefficients were smaller than the coefficients in both years, was designated as being "under operator control". This variable indicated the type of market that apples were being picked for. Picking apples to be sold on the retail market as fresh fruit significantly reduced apple picking rates in both years below rates achieved when apples were being picked for processing.[3] Therefore, if harvest labor is in short supply growers should consider more than the addition to price per bushel which the retail market may provide. The possible loss of a portion of the crop when picking apples for the retail market due to slower picking rates should also be considered when choosing a market outlet.

Among those variables which had the same regression coefficient signs in both years in the variable class "not controlled by operator" only the variables of tree age, weather conditions, and tree spread had regression coefficients which were larger than the standard errors of these coefficients in both years. Weather conditions was the only one of these three variables which was significantly related to worker productivity in both years. Picking in "good" weather reduced productivity in both 1965 and 1966 significantly below what it was in

---

[3]This reduction was significant at less than the 0.0005 level in both years.

weather classed as "bad".[4] The weather variable would not be a factor which the grower could manipulate in the operation of his orchard. However, the age of trees and tree spread, although not significantly related to productivity in both years, should be factors to consider in long range planning. Both of these variables appear to be negatively related to worker productivity in apple picking.[5]

The "people" variable category contained the largest number of variables having standard errors for regression coefficients which were smaller than the coefficients themselves in addition to consistent regression coefficient signs. These two properties were displayed by worker units which were less than 26 years old, over 50 years old, in the female sex category, in the mixed male and female sex category, and in the less than two years of experience class. The worker units in either the young or the old age range had significantly lower picking rates in both years than those in the middle age range.[6] Female worker units had significantly lower productivity in both years than units in the male sex category.[7] In addition, inexperienced worker units approached having significantly lower picking rates than units with two

---

[4]This reduction was significant at least at the 0.008 level in both years.

[5]It should be kept in mind that statistical significance does not necessarily imply an economically significant difference. Nor will a difference which is economically important necessarily show up as statistically significant.

[6]The younger workers had significantly lower rates at least at the 0.009 level in both years while the older units had significantly lower rates at least at the 0.0005 level in both years.

[7]Significantly lower at least at the 0.025 level in both years.

or more years of experience in both years.[8] The picking units of mixed male and female sex had lower productivity than all-male units in both years, but the productivity levels for these two sex groups were significantly different in only one year. These results suggest that growers who have the opportunity should consider the age, sex, and experience of workers in the selection and recruitment of piece-rate harvest labor if timeliness in harvesting is of importance to them.

Model (2)

The number of years of experience a worker unit had picking apples was used as a basis for the interaction terms included in model (2).[9] This model was designed to permit the identification of differences which might exist in the relationship between the independent variables of the model and worker productivity for the two subgroups of workers based on apple picking experience. Model (2) explained approximately 20 percent (R = 0.4476) of the variation in the apple picking rates of workers in 1965 and in 1966 about 29 percent (R = 0.5357) of this variation was accounted for by this model. The regression coefficients obtained for model (2) and the standard errors of these coefficients are presented in Table 26.

Experienced worker units, those having picked apples in two or more previous years, were found to have faster apple picking rates than

---

[8]This difference was significant at less than the 0.0005 level in 1965, but in 1966 it was significant at only the 0.065 level.

[9]The variables included in model (2) are given on Page 31 in Chapter III.

Table 26. Regression Coefficients and Standard Errors, Model (2), 1965 and 1966

	1965		1966	
Variable	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Constant	15.535	1.139	24.019	3.851
X_1	-0.793	.204	-1.294	1.743
X_2	-0.039	.006	-0.086	.042
X_3	-0.024	.273	.973	1.445
X_4	.648	.209	.059	1.095
X_5	-0.873	.188	-4.654	.986
X_6	.058	.689	1.282	1.243
X_7	-0.890	.162	-0.405	.340
X_8	-0.163	.030	-6.828	6.286
X_9	.234	.252	-1.959	1.337
X_{10}	.585	.173	-3.059	1.737
X_{11}	1.186	.367	1.348	.675
X_{12}	-0.967	.242	-1.590	.427
X_{13}	-2.501	.244	-1.444	.387
X_{14}	-1.703	.324	-1.156	.638
X_{15}	-1.292	.328	-1.381	1.175
X_{16}	1.469	.347	.243	1.136
X_{17}	-1.049	1.402	-4.706	6.850
X_{18}	-1.619	.224	.404	1.340
X_{19}	.162	.279	-0.380	.670
X_{20}	-1.311	.208	-0.632	.512
X_{21}	-0.010	.007	-0.075	.116
X_{22}	-0.307	.225	.157	1.352
X_{23}	-0.081	.184	-2.704	.446
X_1X_{17}	*		*	
X_2X_{17}	-0.024	.013	.199	.103
X_3X_{17}	-0.121	.344	.014	2.842
X_4X_{17}	*		*	
X_5X_{17}	*		*	
X_6X_{17}	*		*	
X_7X_{17}	.348	.263	-0.720	.558
X_8X_{17}	-0.101	.053	16.677	13.162
X_9X_{17}	.665	.456	1.433	3.030
$X_{10}X_{17}$	*		*	
$X_{11}X_{17}$	.348	.728	-2.967	1.148
$X_{12}X_{17}$	1.099	.327	1.105	.625
$X_{13}X_{17}$	2.097	.560	-0.106	.794
$X_{14}X_{17}$	-0.022	.520	1.320	2.049
$X_{15}X_{17}$	*		*	
$X_{16}X_{17}$	-0.480	.292	-0.552	.752
$X_{18}X_{17}$	1.206	.394	1.301	3.637
$X_{19}X_{17}$	.500	.416	-1.419	2.079
$X_{20}X_{17}$	1.449	.447	1.515	1.090
$X_{21}X_{17}$	.005	.008	-0.305	.237
$X_{22}X_{17}$	.702	.373	.645	3.356
$X_{23}X_{17}$	-0.398	.303	1.057	.763

*No regression coefficient was calculated.

inexperienced units in both 1965 and 1966 in nine of 13 situations analyzed in which the independent variable representing the situation in model (2) was entered as a zero-one "dummy" variable (see Table 27). However, none of the interaction terms of model (2) were significant. This result indicates that the relationship between the explanatory variables observed in this study and worker productivity did not differ for different subgroups of workers based on their experience picking apples.

Having less than two years of apple picking experience--variable X_{17} in model (2)--tended to reduce apple picking rates in both 1965 and 1966, but this variable was not significant in either year. In Table 27, experienced units are shown to have had higher productivity levels than inexperienced units among female workers, pickers who worked alone, and worker units of Mexican or Puerto Rican ethnic origin. Experienced pickers are also shown to have higher productivity in both years when picking well-pruned trees, when no bonus was paid to workers, when metal picking equipment was used, and when trees over 18 feet tall were being picked. In good weather and when small apples numbering over 175 per bushel were being picked, model (2) also showed experienced workers to pick more bushels of apples per hour than inexperienced ones.

Four situations represented by zero-one variables did not show worker units in one of the experience subclasses to have higher productibity in both the years 1965 and 1966. The variables representing these four situations were 1) worker age less than 26 years, 2) worker age over 50 years, 3) colored ethnic origin, and 4) resident of Michigan. Six situations represented by zero-one variables could not be analyzed in this manner because the necessary regression coefficients were not calculated.

Table 27. Summary of Performance of Experienced and Inexperienced Worker Units for Various Situations Represented by Zero-One Variables, 1965 and 1966, Model (2)

Situation	Picking Rate of Experienced Units Minus Picking Rate of Inexperienced Units 1965	1966
People Variables		
Worker age less than 26 years	-0.050	3.601
Worker age over 50 years	-1.048	4.812
Female sex	1.071	3.386
Mixed male and female sex	*	*
Unit size one person	1.529	5.258
Colored ethnic origin	-0.157	3.405
Mexican or Puerto Rican ethnic origin	.549	6.125
Michigan resident	-0.400	3.191
Variables Under Operator Control		
Stems on all apples	*	*
Tree pruning (well pruned)	1.170	4.692
Tree pruning (some to moderate pruning)	*	*
Picking for retail market	*	*
No bonus payment	.384	3.273
Close supervision	*	*
Metal picking equipment	.701	7.673
Tree height over 18 feet	.347	4.061
Variables Not Controlled by Operator		
Level to gently rolling topography	*	*
Good weather conditions	.701	5.426
Fruit size over 175 apples per bushel	1.447	3.649

*No comparison could be made because appropriate regression coefficients were not calculated.

Three variables in model (2) were entered as continuous variables. None of the interaction terms with worker unit experience for these three: tree age, rate of pay, and tree spread; had consistent regression coefficient signs for the two years data analyzed in this study.

The results of model (2) indicate that worker units having more than one year of apple picking experience tend to have faster apple picking rates than units having no more than one year of experience. This seems to be the case both as an average over all conditions and within a majority of the situations analyzed in model (2). Experienced pickers harvested more bushels of apples per hour in both years in all the situations analyzed in model (2) except four. In these four situations one experience subgroup did not have the fastest picking rates in both years. Although none of the interaction variables in this model were significant in both 1965 and 1966, indicating that none of the relationships between the independent variables in the model and worker productivity were significantly different for the two experience subgroups in both years, the consistency of the performance of experienced pickers over inexperienced ones seems a justifiable basis for recommending that experience be considered in the selection of harvest labor.

Model (3)

The regression coefficients obtained for model (3) and the standard errors of these coefficients are given in Table 28. This model was designed to permit the indentification of differences which might exist in the relationship between the explanatory variables of the model and worker productivity for two worker unit size subgroups.[10]

---

[10]The variables included in model (3) are given on Page 31 in Chapter III.

Table 28. Regression Coefficients and Standard Errors, Model (3), 1965 and 1966

	1965		1966	
Variable	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Constant	15.148	1.011	28.323	3.867
X_1	-0.794	.203	-4.505	2.965
X_2	-0.053	.010	.055	.062
X_3	-0.211	.250	-1.664	1.669
X_4	.525	.207	-0.858	1.195
X_5	-1.250	.302	-13.738	5.939
X_6	1.018	.657	-1.289	1.318
X_7	-0.829	.224	-0.275	.429
X_8	-0.217	.036	20.572	7.659
X_9	.567	.216	-0.146	1.309
X_{10}	.003	.280	.333	2.221
X_{11}	1.497	.624	-1.439	.984
X_{12}	-0.028	.277	-1.173	.521
X_{13}	-2.132	.399	-1.012	.564
X_{14}	-1.097	.650	5.766	2.362
X_{15}	-0.827	.369	-0.452	1.518
X_{16}	*		*	
X_{17}	-1.882	.248	-0.843	.492
X_{18}	-0.884	.339	-0.665	3.572
X_{19}	.084	.311	-0.297	.730
X_{20}	.262	.378	-0.843	.713
X_{21}	-0.008	.021	-0.114	.196
X_{22}	-0.236	.299	-3.100	3.139
X_{23}	.371	.253	-3.685	.633
X_1X_{16}	*		*	
X_2X_{16}	.014	.012	-0.064	.079
X_3X_{16}	*		*	
X_4X_{16}	*		*	
X_5X_{16}	.654	.364	10.299	5.968
X_6X_{16}	*		*	
X_7X_{16}	.112	.271	-0.623	.542
X_8X_{16}	.063	.039	-42.602	11.017
X_9X_{16}	*		*	
$X_{10}X_{16}$	.939	.342	-0.946	1.372
$X_{11}X_{16}$	-0.339	.696	2.396	1.159
$X_{12}X_{16}$	-0.580	.342	-0.266	.635
$X_{13}X_{16}$	.063	.477	-0.925	.676
$X_{14}X_{16}$	-0.543	.709	-6.949	2.436
$X_{15}X_{16}$	*		*	
$X_{17}X_{16}$	-0.334	.305	.687	.618
$X_{18}X_{16}$	-0.224	.385	1.429	3.836
$X_{19}X_{16}$	.443	.409	2.256	1.248
$X_{20}X_{16}$	-1.714	.433	1.330	.917
$X_{21}X_{16}$	.001	.021	-0.090	.232
$X_{22}X_{16}$	.107	.368	4.085	3.599
$X_{23}X_{16}$	-0.831	.306	2.003	.765

*No regression coefficient was calculated.

The independent variables of model (3) explained about 20 percent (R = 0.4491) of the variation in the productivity of apple pickers in 1965. One year later, this model accounted for approximately 31 percent (R = 0.5572) of the variation in worker productivity. Because of problems with singularity, model (3) was fitted with the picking unit size variable omitted. This variable was included in the various interaction terms of the model, however. The omission of the above variable did not permit interpretation of model (3) in the same manner as models (2) and (4). Statements about the levels of picking rates for units in the two size subclasses under various situations could not be made based on model (3). Some inferences about the rates of change in picking rates associated with picking unit size can be made, however.

As mentioned above, the effect of the picking unit size variable (X_{16}) was not estimated in model (3). However, in both models (1) and (2) workers picking alone had faster picking rates in both 1965 and 1966 than workers picking in groups. But the worker unit size variable was significant in only one year in both models. Consistent results for the years 1965 and 1966 were only found in three situations represented by zero-one "dummy" variables in model (3) when the interaction terms of this model were examined. These three situations were: 1) picking for retail market, 2) worker age less than 26 years, and 3) tree height over 18 feet. An additional ten variables of the zero-one type did not give consistent results with respect to the interaction terms in the worker unit size subgroup analysis. Picking apples for the retail market tended to reduce the average productivity of workers in both years compared to picking apples to be processed. But the productivity of individuals picking apples for the retail market was not reduced as much in either year as was the productivity of units of two or more persons picking for this market.[11] Model (3) showed young workers less than 26 years old to have lower picking rates than workers 26-50 years old. The productivity of young workers picking alone was reduced even more than was the productivity of two or more pickers working together in this young age group. Working in trees over 18 feet tall tended to reduce the productivity of all workers in both 1965 and 1966 compared to their productivity in shorter trees. Picking in tall trees did not reduce the picking rates of individual pickers in either year as much as it did the rates of workers in groups of two or more, however.

None of the three situations represented in model (3) by continuous variables displayed consistent results for the interaction term with worker unit size in the two years studied.

With the exception of the one interaction term mentioned above which approached being significant in both 1965 and 1966 the results of model (3) indicate that picking unit size, as measured in this study, was not related to apple picking rates. The one interaction term which approached significance in both years suggests that growers who market apples as fresh fruit should consider separating all workers so that they pick alone if they wish to complete the harvest in the shortest possible time period. Some caution should be used in the interpretation

---

[11]The variable for the interaction between picking apples for the retail market and picking unit size approached being significant at the 0.05 level in both 1965 and 1966. In 1965 it was significant at the 0.069 level and in 1966 it was significant at the 0.081 level.

of this interaction variable, however. The sample of workers used in this study was not stratified to insure that worker units in all age, sex, and experience categories would be uniformly represented in both picking unit size categories. It is possible that a random distribution of units in all age, sex, and experience categories was not present in the two unit size categories observed. For example, groups of workers might have had a higher proportion of female workers and young workers than did the workers in the individual size class as a result of family units tending to pick together. Both of these factors, being female and being young, have been shown in model (1) to reduce apple picking rates. It is possible that the picking unit size variable in model (3) is reflecting the influence of some factor other than the number of pickers who worked together. In any case, growers who choose to separate workers so that they pick alone should be no worse off and some increase in picking rates might be observed if apples are being picked for the retail market.

Model (4)

This model was constructed using the residence of the worker units in interaction terms in an attempt to discover differences in the relationship between the independent variables in the model and apple picking rates for residents and nonresidents of Michigan.[12] The regression coefficients obtained for this model in 1965 and 1966 along with the standard error for each coefficient are contained in Table 29. Model (4) explained about 20 percent (R = 0.4495) of the variation

[12]The variables included in model (4) are given on Page 32 in Chapter III.

observed in apple picking rates in 1965 and in 1966 approximately 29 percent (R = 0.5366) of the observed variation in the dependent variable was accounted for by the independent variables in this model.

The interaction effects of worker unit residence with several of the variables in this model were consistent for the two years observed in this study. However, the regression coefficient for only one of these interaction variables--female sex interacted with Michigan resident--was significant in both 1965 and 1966.[13] Worker units who were non-residents of Michigan did have consistently higher picking rates than those who were Michigan residents in both 1965 and 1966 in all 12 situations represented by zero-one variables for which a comparison was possible (see Table 30).

Models (1), (2), and (4) show Michigan residents (variable X_{20}) to have had slower apple picking rates in both 1965 and 1966 than non-residents of Michigan. However, none of these models indicated that the picking rates of residents were significantly different from those of nonresidents in more than one of the years for which the model was fitted. Even though the residence variable considered alone did not show the productivity of residents and nonresidents of Michigan to be significantly different in both years in these models, nonresidents of Michigan consistently displayed faster picking rates than Michigan residents in every situation examined in model (4). Faster picking rates were displayed in both years by nonresidents among: 1) the age

[13]This variable, while significant at the 0.05 level in 1966, was actually only significant at the 0.055 level in 1965.

Table 29. Regression Coefficients and Standard Errors, Model (4), 1965 and 1966

Variable	1965 Regression Coefficient	1965 Standard Error	1966 Regression Coefficient	1966 Standard Error
Constant	14.813	1.162	16.453	4.480
X_1	-0.736	.203	.522	1.879
X_2	-0.050	.006	.006	.045
X_3	-0.142	.253	.399	1.417
X_4	.636	.210	1.149	1.186
X_5	-0.863	.187	-4.065	.982
X_6	.372	.662	.006	1.251
X_7	-0.816	.141	-0.822	.283
X_8	-0.145	.030	-0.659	5.592
X_9	.221	.243	1.209	1.371
X_{10}	.568	.174	1.205	1.908
X_{11}	1.116	.358	.252	.608
X_{12}	-0.376	.169	-1.201	.309
X_{13}	-1.826	.285	-1.258	.336
X_{14}	-2.145	.331	-1.711	.592
X_{15}	-1.348	.351	1.203	1.875
X_{16}	1.495	.330	2.419	1.840
X_{17}	-2.309	.163	-0.580	.307
X_{18}	-1.088	.191	3.614	1.366
X_{19}	.485	.216	1.250	.810
X_{20}	-1.909	1.790	-14.834	10.556
X_{21}	-0.007	.003	-0.288	.126
X_{22}	-0.052	.197	2.968	1.400
X_{23}	-0.242	.171	-2.286	.364
X_1X_{20}	*		*	
X_2X_{20}	.022	.019	-0.022	.108
X_3X_{20}	*		*	
X_4X_{20}	*		*	
X_5X_{20}	*		*	
X_6X_{20}	*		*	
X_7X_{20}	.044	.341	1.080	1.021
X_8X_{20}	-0.128	.054	7.297	34.038
X_9X_{20}	1.561	.509	5.982	4.142
$X_{10}X_{20}$	*		*	
$X_{11}X_{20}$	1.661	.844	.760	1.783
$X_{12}X_{20}$	-1.307	.592	.066	1.267
$X_{13}X_{20}$	-0.490	.453	-1.450	1.221
$X_{14}X_{20}$	1.037	.548	7.406	2.938
$X_{15}X_{20}$	.438	.876	-0.222	2.931
$X_{16}X_{20}$	-1.286	.775	1.972	2.904
$X_{17}X_{20}$	1.483	.435	1.238	.912
$X_{18}X_{20}$	*		*	
$X_{19}X_{20}$	-2.451	.939	5.855	3.909
$X_{21}X_{20}$	.057	.037	.442	.263
$X_{22}X_{20}$	-0.353	.496	-8.391	3.227
$X_{23}X_{20}$	.538	.368	1.921	3.067

*No regression coefficient was calculated.

Table 30. Summary of Performance of Michigan Resident and Nonresident Worker Units for Various Situations Represented by Zero-One Variables, 1965 and 1966, Model (4)

Situation	Picking Rate of Nonresident Units Minus Picking Rate of Resident Units 1965	1966
People Variables		
Worker age less than 26 years	3.216	14.768
Worker age over 50 years	2.399	16.284
Female sex	.872	7.428
Mixed male and female sex	1.470	15.050
Unit size one person	3.195	12.860
Experience less than two years	.426	13.596
Colored ethnic origin	*	*
Mexican or Puerto Rican ethnic origin	4.360	8.979
Variables Under Operator Control		
Stems on all apples	*	*
Tree pruning (well pruned)	*	*
Tree pruning (some to moderate pruning)	*	*
Picking for retail market	*	*
No bonus payment	.348	8.852
Close supervision	*	*
Metal picking equipment	.248	14.074
Tree height over 18 feet	2.262	23.225
Variables Not Controlled by Operator		
Level to gently rolling topography	*	*
Good weather conditions	1.865	13.754
Fruit size over 175 apples per bushel	1.371	12.913

*No comparison could be made because appropriate regression coefficients were not calculated.

group less than 26 years old, 2) workers over 50 years old, 3) female worker units, 4) mixed male and female units, 5) units consisting of only one person, 6) workers with less than two years of apple picking experience, and 7) units of Mexican or Puerto Rican ethnic origin. Nonresidents of Michigan also had higher productivity levels in both years when: 1) no bonus was paid to workers, 2) using metal picking equipment, and 3) working in trees over 18 feet tall. Finally, nonresidents had faster picking rates than Michigan residents in both years in good weather and when small apples were being picked--those numbering over 175 per bushel. The productivities of residents and nonresidents could not be compared in seven situations represented by zero-one "dummy" variables in model (4) because the necessary regression coefficients were not calculated.

Only one of the three variables in model (4) which were entered as continuous variables had consistent regression coefficient signs for the interaction with worker unit residence in the two years 1965 and 1966. The productivity of Michigan residents was decreased less by an increase in tree spread in both years than was the productivity of nonresidents. The interactions of tree age and rate of pay with worker unit residence did not have consistent effects in the two years observed.

Seven zero-one variables, including the female sex variable previously mentioned as being significant, had consistent interaction effects with the worker unit residence variable in this model in both years for which the model was fitted. A total of eight variables in this model had consistent interaction effects with worker unit residence when the continuous variable, tree spread, was included. The picking rates of workers over 50 years old were reduced more in both years if they were residents than if they were nonresidents. Being a resident of Michigan was associated with less of a reduction in the productivity of female units in both 1965 and 1966 than was being a nonresident. The productivity of an inexperienced picking unit was reduced less in both of these years if it was from Michigan than if it was from some other state. The absence of any bonus payment was associated with more of an increase in the productivity of residents than in the productivity of nonresidents in both 1965 and 1966. Michigan residents had their productivity increased more in each year by using metal picking equipment than did nonresidents. Working in good weather had the effect of reducing the picking rates of residents less in both years than those of nonresidents. And, finally, when small apples were being picked, the productivity of Michigan residents was reduced less than was the productivity of residents of other states in both 1965 and 1966.

The regression coefficients for four of the interactions of zero-one variables with worker unit residence in model (4), in addition to that of the tree spread variable, were larger than their standard errors in both years. This indicates with a fair degree of confidence that the influence of these five variables on the picking rates of Michigan residents was different than their influence on the picking rates of nonresidents. The four "dummy" variables included in interaction terms with worker unit residence which had regression coefficients which were larger than their standard errors in both years were: 1) worker age over 50 years, 2) female sex, 3) less than two years of apple picking experience, and 4) no bonus payment.

The dominant finding throughout the analysis of model (4) is that workers who were not residents of Michigan picked more bushels of apples per hour than did workers who were Michigan residents. This was true regardless of the conditions under which apples were being picked. This finding suggests that apple growers should hire residents of states other than Michigan for apple harvesting if they have a choice between residents and nonresidents and speed in harvesting is a critical factor. This recommendation should not be generalized beyond the sample of workers observed in this study, however. For the most part, the nonresident workers observed in this study were professionals at harvesting fruit and vegetable crops. This type of work was their main or sole source of income. One should not conclude that any non-resident worker would be preferable to a worker from Michigan regardless of his experience, sex, age, or ethnic origin.

One other notable result of model (4), in contrast to those of models (2) and (3), is that in five situations there was a tendency for workers in the two residence classes to be influenced differently by the variables representing these situations in the regression model. This indicates that the worker unit residence variable tends to exhibit differential predictability in five situations. The statistical evidence to support this result is not as conclusive as one would like in four of the five cases. However, the same results in two different years tend to add some additional support to the above findings.

Model (5)

The productivity of worker units in three age subclasses under various situations was examined in model (5).[14] The regression coefficients obtained for this model in 1965 and 1966 are given in Table 31 along with the standard error of each coefficient. In 1965, model (5) explained about 20 percent of the variation observed in apple picking rates.[15] Approximately 31 percent of this variation was accounted for by model (5) in 1966.[16] None of the variables included in model (5) had age subgroup regression coefficients which were significantly different from each other in both years for which this model was fitted.[17]

Workers who were 26-50 years old had significantly higher productivity levels in both 1965 and 1966 than workers in either younger or older age classes according to model (1). But the results of model (5) did not show middle-aged workers to have the fastest picking rates of the three age subgroups in both years in all situations. In fact, workers 26-50 years old had the fastest picking rates in both 1965 and 1966 in only three situations in model (5) which were represented by zero-one variables (see Table 32).

---

[14] The variables included in model (5) are given on Page 36 in Chapter III.

[15] R, the multiple correlation coefficient, was 0.4524 for this model in 1965.

[16] The multiple correlation coefficient, R, was 0.5537 for model (5) in this year.

[17] This was true even at the 0.10 level of significance.

Table 31. Regression Coefficients and Standard Errors, Model (5), 1965 and 1966

Variable	1965 Regression Coefficient	1965 Standard Error	1966 Regression Coefficient	1966 Standard Error
Constant	15.353	.936	23.830	3.842
X_1X_{12}	-0.604	.384	-11.329	20.671
X_1X_{13}	-0.840	.261	-2.841	2.388
X_1X_{14}	*		*	
X_2X_{12}	-0.060	.010	.376	.604
X_2X_{13}	-0.045	.007	-0.131	.064
X_2X_{14}	-0.028	.020	.030	.087
X_3X_{12}	-0.758	.523	-29.970	22.160
X_3X_{13}	.077	.308	1.131	1.818
X_3X_{14}	*		*	
X_4X_{12}	.274	.441	-25.412	16.716
X_4X_{13}	.722	.252	-1.064	1.640
X_4X_{14}	*		*	
X_5X_{12}	-0.777	.393	-6.853	2.452
X_5X_{13}	-0.918	.225	-3.408	1.168
X_5X_{14}	*		*	
X_6X_{12}	*		*	
X_6X_{13}	.386	.646	1.100	1.451
X_6X_{14}	*		*	
X_7X_{12}	-0.321	.275	-0.732	.558
X_7X_{13}	-0.960	.156	-0.986	.385
X_7X_{14}	-0.521	.399	.242	.535
X_8X_{12}	-0.183	.046	2.035	24.539
X_8X_{13}	-0.173	.029	-8.305	7.450
X_8X_{14}	-0.238	.053	-4.994	10.431
X_9X_{12}	.386	.424	-3.014[b]	9.262
X_9X_{13}	.647	.278	.019[b]	1.531
X_9X_{14}	.076	.548	-7.100[b]	2.772
$X_{10}X_{12}$	1.327[a]	.379	-4.202	4.232
$X_{10}X_{13}$	.486[a]	.207	-3.558	2.356
$X_{10}X_{14}$	-0.353[a]	.508	-6.274	2.412
$X_{11}X_{12}$	1.198	.944	-0.817	1.390
$X_{11}X_{13}$	1.320	.383	-0.205	.926
$X_{11}X_{14}$	-0.559	.880	1.271	.951
$X_{16}X_{12}$	-1.818[a]	.533	-9.348	8.641
$X_{16}X_{13}$	-2.094[a]	.326	-1.666	.869
$X_{16}X_{14}$	.522[a]	.812	-0.457	1.543
$X_{17}X_{12}$	-2.279	.567	5.079[b]	2.835
$X_{17}X_{13}$	-1.218	.392	-2.024[b]	1.561
$X_{17}X_{14}$	-1.964	.473	-0.575[b]	.707
$X_{19}X_{12}$	-0.689	.439	-15.217	22.043
$X_{19}X_{13}$	-1.347	.218	.916	1.541
$X_{19}X_{14}$	-1.323	.560	-4.940	3.293

Table 31. (cont'd.)

Variable	1965 Regression Coefficient	1965 Standard Error	1966 Regression Coefficient	1966 Standard Error
$X_{20}X_{12}$	.811	.422	-2.369	2.177
$X_{20}X_{13}$	.118	.252	-0.542	.970
$X_{20}X_{14}$	-0.592	.790	-3.489	2.141
$X_{21}X_{12}$	.339[b]	.519	4.308	2.630
$X_{21}X_{13}$	1.499[b]	.367	-0.245	1.577
$X_{21}X_{14}$	*		*	
$X_{22}X_{12}$	-1.772[a]	.300	-0.058	.589
$X_{22}X_{13}$	-2.478[a]	.179	-0.632	.517
$X_{22}X_{14}$	.415[a]	.604	-0.113	.818
$X_{23}X_{12}$	-0.765	.587	.360	1.648
$X_{23}X_{13}$	-0.959	.217	-0.588	1.050
$X_{23}X_{14}$	-1.186	.421	.236	.864
$X_{24}X_{12}$	-0.007	.008	.973	.901
$X_{24}X_{13}$	-0.007	.003	-0.020	.160
$X_{24}X_{14}$	.042	.045	-0.028	.201
$X_{25}X_{12}$	.756[a]	.387	-15.581	18.367
$X_{25}X_{13}$	-0.308[a]	.228	-0.325	1.563
$X_{25}X_{14}$	-0.958[a]	.502	-4.696	3.208
$X_{26}X_{12}$	.061	.340	-1.857[b]	.671
$X_{26}X_{13}$	-0.274	.189	-1.811[b]	.533
$X_{26}X_{14}$	.036	.419	-3.803[b]	.752

*No regression coefficient was calculated.

[a]Regression coefficients for the age subgroups are significantly different from each other at the 0.05 level in this situation for the year specified.

[b]Regression coefficients for the age subgroups are significantly different from each other at the 0.10 level in this situation for the year specified.

Table 32. Summary of Performance of Young, Middle-Aged, and Old Worker Units for Various Situations Represented by Zero-One Variables, 1965 and 1966, Model (5)

Situation	Year	Age of Worker Unit (Years) Less than 26	26-50	Over 50
People Variables				
Female sex	1965	-1.818	-2.094	.522[a]
	1966	-9.348	-1.666	-0.457[a]
Mixed male and female sex	1965	-2.279	-1.218	-1.964
	1966	5.079	-2.024	-0.575
Unit size one person	1965	.339	1.499	*
	1966	4.308	-0.245	*
Experience less than two years	1965	-1.772	-2.478[b]	.415
	1966	-0.058	-0.632[b]	-0.113
Colored ethnic origin	1965	-0.689	-1.347	-1.323
	1966	-15.217	.916	-4.940
Mexican or Puerto Rican ethnic origin	1965	.811	.118	-0.592[b]
	1966	-2.369	-0.542	-3.489[b]
Michigan resident	1965	-0.765[a]	-0.959	-1.186
	1966	.360[a]	-0.588	.236
Variables Under Operator Control				
Stems on all apples	1965	-0.604	-0.840	*
	1966	-11.329	-2.841	*
Tree pruning (well pruned)	1965	-0.758[b]	.077[a]	*
	1966	-29.970[b]	1.131[a]	*
Tree pruning (some to moderate pruning)	1965	.274[b]	.722[a]	*
	1966	-25.412[b]	-1.064[a]	*
Picking for retail market	1965	-0.777	-0.918	*
	1966	-6.853	-3.408	*
No bonus payment	1965	.386	.647[a]	.076[b]
	1966	-3.014	.019[a]	-7.100[b]
Close supervision	1965	1.327	.486	-0.353[b]
	1966	-4.202	-3.558	-6.274[b]
Metal picking equipment	1965	1.198	1.320	-0.559
	1966	-0.817	-0.205	1.271
Tree height over 18 feet	1965	.756	-0.308	-0.958
	1966	-15.581	-0.325	-4.696
Variables Not Controlled by Operator				
Level to gently rolling topography	1965	*	.386	*
	1966	*	1.100	*
Good weather conditions	1965	-0.321	-0.960[b]	-0.521
	1966	-0.732	-0.986[b]	.242
Fruit size over 175 apples per bushel	1965	.061	-0.274	.036
	1966	-1.857	-1.811	-3.803

Table 32. (cont'd.)

[*]No regression coefficient was calculated.

[a]Highest picking rates of age subgroups observed in both years in this situation.

[b]Lowest picking rates of age subgroups observed in both years in this situation.

Note: The coefficients in the above table do not represent apple picking rates for the different age subgroups in various situations. Rather, they represent deviations of that subgroup from the average of workers of all ages in the omitted category of the zero-one "dummy" variable in question.

The results of model (5) show five cases in which one age subgroup had the fastest picking rates in both 1965 and 1966 in situations represented by zero-one "dummy" variables. Workers less than 26 years old had the highest productivity in both of these years among pickers who were residents of Michigan. Workers over 50 years old picked more bushels of apples per hour in both years than either of the other two age groups among female worker units. Pickers in the 26-50 age range had the highest productivity levels of the three age groups in three situations in model (5): 1) when trees were well-pruned, 2) when trees had only some to moderate pruning, and 3) when no bonus payment was made.

There were seven situations in model (5) in which one group had the slowest picking rate of the three age subgroups in both 1965 and 1966. Young workers and middle-aged workers were each involved in two of these situations and three of the situations involved older units. Well-pruned trees and some to moderate tree pruning were the two situations in which workers under 26 years old had the lowest productivity levels in both years. Middle-aged pickers displayed the lowest productivity levels of the three age subgroups when apples were being picked under good weather conditions and also among those workers having less than two years of apple picking experience. Worker units over 50 years old had the lowest picking rates in three situations: 1) when no bonus payment was made, 2) under close supervision, and 3) among Mexican or Puerto Rican workers.

None of the sets of regression coefficients calculated for worker unit age subgroups in the three situations represented by a continuous variable in model (5) were consistent for the two years observed in this study.

Although worker unit age was significantly related to worker productivity in model (1) for both the years 1965 and 1966, a consistent pattern was found in only a few cases in model (5) with respect to the productivity of workers in different age subgroups. And in no case did any of the independent variables in model (5) display relationships with apple picking rates which differed significantly for the three age subgroups of workers analyzed in the model. The results of the analysis of model (5) are of interest because of the contrast with model (1) in the case of four variables. Recall that model (1) showed middle-aged pickers to have the highest productivity levels of the three age groups in both 1965 and 1966; and that workers over 50 years old had the slowest picking rates in both years. But model (5) showed workers over 50 years old to have the highest productivity levels in both years among female workers. This model also showed workers in the youngest age group to be the fastest pickers in both years among workers who were Michigan residents. And middle-aged pickers who had the highest productivity levels on the average in model (1) were shown to have the slowest picking rates of the three age classes when only inexperienced workers were considered or when pickers were working under good weather conditions. With the possible exception of these four cases it appears that the selection of apple harvest labor could be made on the basis of the age of the worker without considering the conditions under which apples were to be picked. Even the above four cases which were exceptions did not have significantly different effects on the productivity of the age subgroups although the relative productivity of the age subgroups was the same in both years in each of the four cases.

Model (6)

The regression coefficients obtained for the three sex subgroups under various situations in model (6) for the two years 1965 and 1966 are given in Table 33. The standard error of each coefficient is also included in this table. Model (6) was designed to help identify subgroups of workers, based on their sex, which might respond differently to certain variables observed in this study which were assumed to be related to apple picking rates.[18] In 1965 model (6) explained 20 percent (R = 0.4473) of the variation in apple picking rates observed in this study. Approximately 33 percent (R = 0.5763) of the observed variation in worker productivity was accounted for by model (6) in 1966. There were four cases for this model in which the effects of an independent variable on worker productivity differed significantly in both 1965 and 1966 for workers in the different age subgroups analyzed. However, there was only one of these four situations in which the signs

---

[18]The variables included in model (6) are given on Page 36 in Chapter III.

and relative magnitudes of the regression coefficients for the sex subgroups were consistent in these two years.

The results of model (1) indicated that male worker units had faster picking rates in both years observed than either of the other two sex subgroups. But when the productivity of worker units in the three sex classes was analyzed in model (6) the all-male units had the fastest picking rates in only two situations represented by zero-one variables in the model (see Table 34). These two situations were when apples were picked so that the stems remained on all apples and among units of Mexican or Puerto Rican ethnic origin. Female units had the highest productivity of the three sex subgroups in both years when only workers over 50 years old were considered. The mixed male and female units displayed faster picking rates than either of the other two sex groups in 1965 and 1966 in three situations: 1) when no bonus payment was made, 2) among workers aged less than 26 years, and 3) among units of colored ethnic origin.

There were four situations in model (6) in which one sex class was shown to have the lowest picking rate in both of the years studied. There were two of these situations, when no bonus payment was made and among units of colored ethnic origin, in which male worker units had the slowest picking rates observed in both years. The other two situations in which one sex subgroup had the lowest productivity in both 1965 and 1966 were when stems were preserved on all apples being picked and among Mexican or Puerto Rican workers. In these two situations the mixed male and female units had the lowest productivity.

The picking rates of the sex subgroups were significantly different from each other in both 1965 and 1966 in three situations

Table 33. Regression Coefficients and Standard Errors, Model (6), 1965 and 1966

	1965		1966	
Variable	Regression Coefficient	Standard Error	Regression Coefficient	Standard Error
Constant	15.217	.871	13.723	4.691
X_1X_{15}	-0.863	.253	-1.724	2.796
X_1X_{16}	*		*	
X_1X_{17}	-1.116	.384	-5.431	3.308
X_2X_{15}	-0.038	.007	.045[b]	.057
X_2X_{16}	-0.026	.018	8.100[b]	3.425
X_2X_{17}	-0.049	.012	-0.020[b]	.098
X_3X_{15}	-0.558	.316	5.672	6.448
X_3X_{16}	-0.165	.552	36.743	18.367
X_3X_{17}	.053	.449	1.533	2.280
X_4X_{15}	.485	.258	8.556[b]	6.104
X_4X_{16}	*		*	
X_4X_{17}	.628	.388	-2.413[b]	1.805
X_5X_{16}	-0.516	.235	-2.309[a]	1.164
X_5X_{17}	-1.057	.597	58.451[a]	27.484
X_5X_{18}	*		*	
X_6X_{15}	*		*	
X_6X_{16}	*		*	
X_6X_{17}	-0.264	1.340	-1.648	1.379
X_7X_{15}	-0.767	.159	-0.830	.353
X_7X_{16}	-0.211	.488	-0.976	1.107
X_7X_{17}	-0.763	.245	-0.348	.428
X_8X_{15}	-0.157[a]	.031	-24.311[a]	8.222
X_8X_{16}	*		*	
X_8X_{17}	-0.265[a]	.042	16.314[a]	7.950
X_9X_{15}	.109[b]	.277	-1.174[b]	1.443
X_9X_{16}	*		*	
X_9X_{17}	.899[b]	.366	3.871[b]	2.559
$X_{10}X_{15}$	.997	.217	.254	2.241
$X_{10}X_{16}$	*		*	
$X_{10}X_{17}$	*		*	
$X_{11}X_{15}$	1.112[a]	.377	1.135[c]	.688
$X_{11}X_{16}$	-5.280[a]	1.308	.212[c]	1.385
$X_{11}X_{17}$	1.281[a]	.692	-1.399[c]	.978
$X_{12}X_{15}$	-0.491	.204	-1.435	.389
$X_{12}X_{16}$	-0.639	.524	-1.314	1.211
$X_{12}X_{17}$	-0.256	.313	-1.240	.524
$X_{14}X_{15}$	-2.175	.272	-2.084	.391
$X_{14}X_{16}$	-0.959	.782	-0.701	1.398
$X_{14}X_{17}$	-2.296	.423	-0.931	.562
$X_{19}X_{15}$	-1.249	.227	-0.703	1.638
$X_{19}X_{16}$	*		*	
$X_{19}X_{17}$	-0.551	.391	.796	3.701
$X_{20}X_{15}$	.575	.278	2.561[a]	1.157
$X_{20}X_{16}$	*		*	
$X_{20}X_{17}$	.406	.321	-1.069[a]	.789

Table 33. (cont'd.)

Variable	1965 Regression Coefficient	1965 Standard Error	1966 Regression Coefficient	1966 Standard Error
$X_{21}X_{15}$	1.262	.344	4.802	1.485
$X_{21}X_{16}$	1.194	.610	5.600	3.425
$X_{21}X_{17}$	*		*	
$X_{22}X_{15}$	-2.202	.185	-0.289	.410
$X_{22}X_{16}$	*		*	
$X_{22}X_{17}$	-2.054	.271	-0.908	.494
$X_{23}X_{15}$	-1.500[a]	.222	.511	.576
$X_{23}X_{16}$	*		*	
$X_{23}X_{17}$	.250[a]	.417	-0.154	.786
$X_{24}X_{15}$	-0.008	.003	-0.237[b]	.136
$X_{24}X_{16}$	-0.005	.005	-16.246[b]	6.868
$X_{24}X_{17}$	-0.005	.023	-0.102[b]	.209
$X_{25}X_{15}$	-0.234	.239	-0.078[a]	1.585
$X_{25}X_{16}$	-0.610	.554	212.887[a]	88.004
$X_{25}X_{17}$	.223	.321	-2.138[a]	3.350
$X_{26}X_{15}$	-0.433[b]	.195	-1.789[a]	.450
$X_{26}X_{16}$	.059[b]	.529	-1.016[a]	1.408
$X_{26}X_{17}$	.334[b]	.270	-3.677[a]	.634

*No regression coefficient was calculated.

[a]Regression coefficients for the sex subgroups are significantly different from each other at the 0.05 level in this situation for the year specified.

[b]Regression coefficients for the sex subgroups are significantly different from each other at the 0.10 level in this situation for the year specified.

[c]Regression coefficients for the sex subgroups approached being significantly different from each other at the 0.10 level in this situation for the year specified. They were significantly different at the 0.107 level in this case.

Table 34. Summary of Performance of Male, Female, and Mixed Male and Female Worker Units for Various Situations Represented by Zero-One Variables, 1965 and 1966, Model (6)

Situation	Year	Sex of Worker Unit		
		Male	Female	Mixed
People Variables				
Worker age less than	1965	-0.491	-0.639	-0.256[a]
26 years	1966	-1.435	-1.314	-1.240[a]
Worker age over 50 years	1965	-2.175	-0.959[a]	-2.296
	1966	-2.084	-0.701[a]	-0.931
Unit size one person	1965	1.262	1.194	*
	1966	4.802	5.600	*
Experience less than	1965	-2.202	*	-2.054
two years	1966	-0.289	*	-0.908
Colored ethnic origin	1965	-1.249[b]	*	-0.551[a]
	1966	-0.703[b]	*	.796[a]
Mexican or Puerto Rican	1965	.575[a]	*	.406[b]
ethnic origin	1966	2.561[a]	*	-1.069[b]
Michigan resident	1965	-1.500	*	.250
	1966	.511	*	-0.154
Variables Under Operator Control				
Stems on all apples	1965	-0.863[a]	*	-1.116[b]
	1966	-1.724[a]	*	-5.431[b]
Tree pruning (well pruned)	1965	-0.558	-0.165	.053
	1966	5.672	36.743	1.533
Tree pruning (some to	1965	.485	*	.628
moderate pruning)	1966	8.556	*	-2.413
Picking for retail market	1965	-0.516	-1.057	*
	1966	-2.309	58.451	*
No bonus payment	1965	.109[b]	*	.899[a]
	1966	-1.174[b]	*	3.871[a]
Close supervision	1965	.997	*	*
	1966	.254	*	*
Metal picking equipment	1965	1.112	-5.280	1.281
	1966	1.135	.212	-1.399
Tree height over 18 feet	1965	-0.234	-0.610	.223
	1966	-0.078	212.887	-2.138
Variables Not Controlled by Operator				
Level to gently rolling	1965	*	*	-0.264
topography	1966	*	*	-1.648
Good weather conditions	1965	-0.767	-0.211	-0.763
	1966	-0.830	-0.976	-0.348
Fruit size over 175 apples	1965	-0.433	.059	.334
per bushel	1966	-1.789	-1.016	-3.677

Table 34. (cont'd.)

*No regression coefficient was calculated.

[a]Highest picking rates of sex subgroups observed in both years in this situation.

[b]Lowest picking rates of sex subgroups observed in both years in this situation.

Note: The coefficients in the above table do not represent apple picking rates for the different sex subgroups in various situations. Rather, they represent deviations of that subgroup from the average of workers in all sex groups in the omitted category of the zero-one "dummy" variable in question.

represented by zero-one "dummy" variables in model (6). When no bonus payment was made to workers the productivity of mixed male and female units was significantly higher at the 0.10 level than that of all-male units in both years.[19] The productivities of the various sex subgroups were also significantly different from each other in both years when small apples numbering over 175 per bushel were being picked[20] and when metal picking equipment was being used.[21] However, in these latter two situations no pattern with respect to the relative picking rates of the subgroups could be determined as holding in both years.

Neither the variables tree age nor tree spread which were entered as continuous variables in model (6) had an influence on any

---

[19]No regression coefficient was calculated for female units in this situation.

[20]In 1965 they were significantly different at the 0.10 level and in 1966 at the 0.05 level.

[21]In 1965 the picking rates of workers using metal equipment differed at the 0.05 level. But in 1966 the rates of workers using this equipment only closely approached being significantly different at the 0.10 level. They were different at the 0.107 level in that year.

of the sex classes which was significantly different from zero in both years at the 0.05 level. The sex subgroup regression coefficients for both of these variables were significantly different from each other at the 0.10 level in 1966, but in 1965 these coefficients were not significantly different from each other for either variable. The rate of pay the worker units received for picking apples was also entered as a continuous variable in model (6). Both of the sex subgroup coefficients calculated for this variable were significantly different from zero in both years.[22] The sex subgroup coefficients for this variable were also significantly different from each other at the 0.05 level in both years. However, in 1965 an increase in the rate of pay tended to decrease the productivity of male units less than it decreased the productivity of mixed male and female units while in 1966 an increase in payment rates decreased male unit productivity while tending to increase mixed unit picking rates.

The analysis of model (6) was hindered by a lack of observations for the female sex class. A regression coefficient was only calculated for this class in two cases mentioned above as having consistent results with respect to the relative productivity of the sex subgroups (see Table 34). The results of model (6) do indicate, however, that a blanket recommendation should not be made as to the advisability of hiring apple harvest labor on the basis of sex. If speed in harvesting is important, model (6) suggests that female workers are preferable to male workers if only workers over 50 years old are being considered.

---

[22]No coefficient was calculated for the female sex subgroup in this case.

If only Mexican or Puerto Rican pickers were being considered, model (6) indicates that male workers should be the faster pickers. But among workers of colored ethnic origin males do not appear to be the fastest pickers. Females would appear to be preferable to males among colored workers.[23] Finally, it may be advisable to hire young married couples to harvest apples if a choice must be made from among younger workers. This inference is made from the results in model (6) showing the mixed male and female sex class to have the fastest picking rates among workers less than 26 years old. It seems unlikely that the practice of combining young males and females in picking units would help improve their productivity unless some factor like the necessity of providing for a family were present. The above three observations, although based on consistent results for the two years 1965 and 1966, cannot be supported with any significant statistical results.

Model (7)

An attempt was made to identify differences in the apple picking rates of workers in three ethnic origin groups under various situations in model (7).[24] A summary of the regression coefficients estimated for this model in both 1965 and 1966 is given in Table 35 along with the standard error of each coefficient. Model (7) accounted for roughly

---

[23]Only an inference can be made here since a regression coefficient was not calculated for colored females. This inference is based on the observation that mixed male and female picking units had faster picking rates than all-male units in both years among colored units.

[24]The variables included in model (7) are given on Page 36 in Chapter III.

19 percent (R = 0.4346) of the variation observed in apple picking rates in 1965. In 1966 about 29 percent (R = 0.5359) of the observed variation in productivity was explained by model (7). There were only two situations examined in this model in which the productivities of workers in the ethnic subgroups differed significantly in both years observed in this study.

Workers of one particular ethnic origin did not have consistently higher productivity in both 1965 and 1966 according to model (1). This result indicates that other factors are more closely related to worker productivity in apple picking than is ethnic origin. Even though a consistent relationship was not found in model (1) between ethnic origin and productivity in the two years observed, several situations were found in model (7) in which one ethnic origin subgroup had consistently higher or lower productivity than the other two groups in both 1965 and 1966.

There were six situations of the 18 in model (7) represented by zero-one "dummy" variables which were associated with one ethnic subgroup having the fastest picking rate in both 1965 and 1966 (see Table 36). White picking units had the fastest rates in only one of these situations; when working in good weather. There were two situations in which colored workers displayed the highest productivity levels and Mexican or Puerto Rican pickers had the highest productivity in three cases. Colored worker units had faster picking rates in both years among pickers under 26 years old and among those units having less than two years of apple picking experience. When trees over 18 feet tall were being picked, the Mexican or Puerto Rican units picked

Table 35. Regression Coefficients and Standard Errors, Model (7), 1965 and 1966

Variable	1965 Regression Coefficient	1965 Standard Error	1966 Regression Coefficient	1966 Standard Error
Constant	12.844	1.250	25.451	4.106
X_1X_{18}	.022	.285	-3.546	2.652
X_1X_{19}	*		*	
X_1X_{20}	*		*	
X_2X_{18}	-0.047[a]	.007	-0.044[a]	.044
X_2X_{19}	-0.006[a]	.010	-0.392[a]	.112
X_2X_{20}	*		*	
X_3X_{18}	*		*	
X_3X_{19}	*		*	
X_3X_{20}	2.590	.690	-1.335	2.997
X_4X_{18}	-0.053[a]	.214	-1.318	1.529
X_4X_{19}	1.465[a]	.281	.429	2.958
X_4X_{20}	2.741[a]	.647	.076	3.801
X_5X_{18}	-0.581	.269	-4.418	.987
X_5X_{19}	*		*	
X_5X_{20}	*		*	
X_6X_{18}	.959	.684	.099	1.347
X_6X_{19}	*		*	
X_6X_{20}	*		*	
X_7X_{18}	-0.431	.193	-0.312[c]	.324
X_7X_{19}	-0.686	.238	-1.714[c]	.573
X_7X_{20}	-0.447	.281	-0.597[c]	1.514
X_8X_{18}	-0.150[a]	.028	-2.980	5.588
X_8X_{19}	*		*	
X_8X_{20}	-0.857[a]	.113	8.425	28.729
X_9X_{18}	.246	.236	-2.864	1.491
X_9X_{19}	*		*	
X_9X_{20}	*		*	
$X_{10}X_{18}$	.062[a]	.240	-3.887	1.922
$X_{10}X_{19}$	*		*	
$X_{10}X_{20}$	3.624[a]	.532	-19.619	14.468
$X_{11}X_{18}$	.721	.485	.481	.543
$X_{11}X_{19}$	1.568	.495	-1.669	1.750
$X_{11}X_{20}$	4.735	2.889	-18.975	17.406
$X_{12}X_{18}$	-0.952	.249	-1.389	.393
$X_{12}X_{19}$	-0.324	.333	-0.594	.523
$X_{12}X_{20}$	-0.382	.285	-0.822	1.394
$X_{14}X_{18}$	-2.422	.281	-1.499	.365
$X_{14}X_{19}$	-1.559	.425	-1.109	.678
$X_{14}X_{20}$	-2.917	.719	-1.100	2.290
$X_{16}X_{18}$	-1.084	.374	-1.663	.600
$X_{16}X_{19}$	-1.837	.538	.052	2.931
$X_{16}X_{20}$	*		*	

Table 35. (cont'd.)

Variable	1965 Regression Coefficient	1965 Standard Error	1966 Regression Coefficient	1966 Standard Error
$X_{17}X_{18}$	-1.740[a]	.547	-2.131	1.470
$X_{17}X_{19}$	*		*	
$X_{17}X_{20}$	.461[a]	.596	-0.034	2.919
$X_{21}X_{18}$	.789[a]	.520	-0.481	1.442
$X_{21}X_{19}$	1.690[a]	.297	.360	.748
$X_{21}X_{20}$	3.442[a]	.589	3.551	2.460
$X_{22}X_{18}$	-2.420[a]	.241	-0.754[a]	.359
$X_{22}X_{19}$	-1.649[a]	.254	.799[a]	.569
$X_{22}X_{20}$	*		*	
$X_{23}X_{18}$	-1.423	.242	.559	.589
$X_{23}X_{19}$	-0.795	.321	.523	1.169
$X_{23}X_{20}$	*		*	
$X_{24}X_{18}$	*		*	
$X_{24}X_{19}$	*		*	
$X_{24}X_{20}$	-0.006	.003	-0.046	.715
$X_{25}X_{18}$	-2.115	2.276	-1.946	1.491
$X_{25}X_{19}$	*		*	
$X_{25}X_{20}$	1.963	2.265	.990	4.934
$X_{26}X_{18}$	4.662[a]	1.308	-2.623	.417
$X_{26}X_{19}$	-4.852[a]	1.329	-1.353	.732
$X_{26}X_{20}$	*		*	

*No regression coefficient was calculated.

[a]Regression coefficients for the ethnic origin subgroups are significantly different from each other at the 0.05 level in this situation for the year specified.

[b]Regression coefficients for the ethnic origin subgroups are significantly different from each other at the 0.10 level in this situation for the year specified.

[c]Regression coefficients for the ethnic origin subgroups approached being significantly different from each other at the 0.10 level in this situation for the year specified. They were significantly different at the 0.105 level in this case.

more bushels of apples per hour in both years than either of the other two ethnic subgroups. They also picked more bushels of apples per hour in both 1965 and 1966 when only mixed male and female units were considered and among those units made up of only one person working alone.

White picking units were found to have the lowest productivity levels in both years among the three ethnic subgroups in six situations represented by zero-one "dummy" variables in this model. These situations included: 1) picking trees with some to moderate pruning, 2) picking trees over 18 feet tall, 3) worker units under 26 years old, 4) mixed male and female worker units, 5) picking units consisting of only one person, and 6) worker units having less than two years of experience picking apples. Only one other situation was observed in which an ethnic class had the lowest productivity in both 1965 and 1966. Colored workers had the slowest picking rates in both these years when picking under good weather conditions.

In only one situation represented by zero-one variables, that in which worker units had less than two years experience, did the performance of ethnic subgroups differ significantly from each other in both of the two years studied. Inexperienced colored workers had significantly higher productivity levels than inexperienced white pickers in both 1965 and 1966.[25]

One of the three situations represented by continuous variables in model (7) had significantly different influences on the ethnic

[25]A coefficient for Mexican or Puerto Rican workers with less than two years of experience was not calculated.

Table 36. Summary of Performance of White, Colored, and Mexican or Puerto Rican Worker Units for Various Situations Represented by Zero-One Variables, 1965 and 1966, Model (7)

Situation	Year	Ethnic Origin of Worker Unit: White	Colored	Mexican or Puerto Rican
People Variables				
Worker age less than 26 years	1965	-0.952[b]	-0.324[a]	-0.382
	1966	-1.389[b]	-0.594[a]	-0.822
Worker age over 50 years	1965	-2.422	-1.559	-2.917
	1966	-1.499	-1.109	-1.100
Female sex	1965	-1.084	-1.837	*
	1966	-1.663	.0582	*
Mixed male and female sex	1965	-1.740[b]	*	.461[a]
	1966	-2.131[b]	*	-0.034[a]
Unit size one person	1965	.789[b]	1.690	3.442[a]
	1966	-0.481[b]	.360	3.551[a]
Experience less than two years	1965	-2.420[b]	-1.649[a]	*
	1966	-0.754[b]	.799[a]	*
Michigan resident	1965	-1.423	-0.795	*
	1966	.559	.523	*
Variables Under Operator Control				
Stems on all apples	1965	.022	*	*
	1966	-3.546	*	*
Tree pruning (well pruned)	1965	*	*	2.590
	1966	*	*	-1.335
Tree pruning (some to moderate pruning)	1965	-0.053[b]	1.465	2.741
	1966	-1.318[b]	.429	.076
Picking for retail market	1965	-0.581	*	*
	1966	-4.418	*	*
No bonus payment	1965	.246	*	*
	1966	-2.864	*	*
Close supervision	1965	.062	*	3.624
	1966	-3.887	*	-19.619
Metal picking equipment	1965	.721	1.568	4.735
	1966	.481	-1.669	-18.975
Tree height over 18 feet	1965	-2.115[b]	*	1.963[a]
	1966	-1.946[b]	*	.990[a]
Variables Not Controlled by Operator				
Level to gently rolling topography	1965	.959	*	*
	1966	.099	*	*
Good weather conditions	1965	-0.431[a]	-0.680[b]	-0.447
	1966	-0.312[a]	-1.714[b]	-0.597
Fruit size over 175 apples per bushel	1965	4.662	-4.852	*
	1966	-2.623	-1.353	*

Table 36. (cont'd)

*No regression coefficient was calculated.

[a]Highest picking rates of ethnic origin subgroups observed in both years in this situation.

[b]Lowest picking rates of ethnic origin subgroups observed in both years in this situation.

Note: The coefficients in the above table do not represent apple picking rates for the different ethnic origin subgroups in various situations. Rather, they represent deviations of that subgroup from the average of workers in all ethnic groups in the omitted category of the zero-one "dummy" variable in question.

subgroups analyzed in both 1965 and 1966. The effect of tree age on white pickers was significantly different from its effect on colored workers in both years.[26] Even though the influence of tree age on productivity was significantly different for these two ethnic subgroups in both years the relative magnitude of the influence differed in the two years. In 1965, a given increase in tree age tended to decrease the productivity of white workers more than it did that of colored pickers, but in 1966 this result was reversed. For neither ethnic subgroup was the effect of tree age significantly different from zero in both years. The other two situations represented by continuous variables, the rate of payment per bushel for picking apples and tree spread, did not have any ethnic subgroup coefficients which were significantly different from zero in both years. Nor were the ethnic subgroup coefficients within one of these situations

---

[26]No coefficient was calculated for Mexican or Puerto Rican units in this situation.

significantly different from each other in both years.[27] The productivity of Mexican or Puerto Rican pickers was reduced as tree spread increased in both years, however.

There were several cases in model (7) in which a comparison could not be made between ethnic subgroups because the necessary regression coefficients were not calculated. This hindered the analysis of worker productivity differences related to ethnic origin. No one of the three ethnic groups observed in this study demonstrated superior productivity in apple picking. And in only one case is there any significant statistical evidence to support the contention that the apple picking abilities of ethnic groups differ. This was the case in model (7) in which there was a significant difference in the productivities of colored and white pickers who had less than two years of apple picking experience. The consistently higher or lower picking rates in both years observed in this study which were associated with one ethnic subgroup suggests that under certain conditions one ethnic group may be expected to out-perform the others. Therefore, if timeliness in apple harvesting is of importance to the apple grower he might give some consideration to the consistent relationships discovered with respect to the ethnic origin of workers in his hiring and managerial practices. For example, if his trees are tall (over 18 feet) he should consider hiring Mexican or Puerto Rican workers if they are available since they demonstrated the fastest picking rates of the three ethnic subgroups in both 1965 and

---

[27]Significant differences between ethnic subgroups for the tree spread variable were not possible since only one coefficient was calculated.

1966 in tall trees. But as mentioned above, significant differences in apple picking rates between ethnic groups are not supported statistically by the results of this study.

A frequently expressed preference of apple growers for workers of Spanish-American ethnic origin is not supported by the results of this study. The apple picking rates of these workers do not appear to be different from those of white or colored workers based on statistical analysis. Apple growers do, however, consider more than apple picking rates in their choice of workers. Worker turnover, supervisory problems, and repair and maintenance costs for equipment and worker housing are important factors considered by growers which are not reflected by apple picking rates.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Data collected in Michigan during two apple harvest seasons, 1965 and 1966, were used in this study to examine factors related to the picking rates of workers harvesting apples on a piece-rate system. A regression equation containing 23 independent variables was fitted by ordinary least squares to the data obtained in each of the above years to determine the relationship of selected worker characteristics, management practices, orchard characteristics, and weather conditions to the performance of workers picking apples.

Three worker characteristics were found to be significantly related to apple picking rates at the 0.05 level. Workers who were less than 26 years old harvested fewer bushels of apples per hour than did pickers aged 26-50 years. Older workers, those over 50 years old, picked fewer bushels of apples per hour than workers 26-50 years old. And male pickers had faster picking rates than female workers.

Only one management practice observed in this study was significantly related, at the 0.05 level, to the productivity of workers harvesting apples. When workers picked apples to be sold as fresh fruit they picked fewer bushels per hour than when picking apples to be processed.

The only other factor found to be significantly related to worker productivity at the 0.05 level in this study was weather. The picking rates of workers under weather conditions classed as "good" were lower than they were under "bad" weather conditions.

Four other variables examined in this study tended to be related to the apple picking rates of workers. The regression coefficients of these four variables were larger than their standard errors.

Two of the variables tending to be related to apple picking rates were worker characteristics. Having fewer than two previous years of apple picking experience was associated with slower apple picking rates than having two or more years of experience picking apples. Picking units which contained both male and female workers picked fewer bushels of apples per hour than did units containing only male workers.

The other two variables which displayed a tendency to be related to worker unit productivity were orchard characteristics. An increase in either the age of the trees or the spread of the trees being picked resulted in a decrease in the apple picking rates of workers.

In addition to analyzing factors related to apple picking rates in this study, an attempt was made to verify the existence of differential predictability with respect to six selected worker unit characteristics. Two subgroups of workers were identified for the worker unit characteristics of experience, size, and residence. The two subgroups used for the experience variable were less than two years and two years or more of apple picking experience. Individual pickers working alone made up one size subgroup and pickers working in groups of two or more made up the other. The two residence subgroups consisted of residents and nonresidents of Michigan.

Three worker subgroups were identified for the worker unit characteristics of age, sex, and ethnic origin. The age variable was separated into subgroups of less than 26, 26-50, and over 50 years of age. Male, female, and mixed male and female workers were the sex subgroups identified. And white, colored, and Mexican or Puerto Rican workers made up the ethnic origin subgroups.

Six regression equations which included the selected worker unit characteristics in interaction terms were fitted to the data for each of the two years 1965 and 1966 by the ordinary least squares method. The objective of this procedure was to identify independent variables which had differing relationships to apple picking rates for the subgroups of workers identified.

None of the variables analyzed in this study exhibited differential predictability with respect to the two subgroups of workers identified on the basis of apple picking experience. Experienced workers did have consistently faster picking rates than workers who were classified as inexperienced under all orchard conditions analyzed in this study, however.

One variable, the type of market apples were picked for, did display a tendency toward differential predictability with respect to the size of the picking unit. The productivity of individual pickers was reduced less by picking apples for the retail market than was the productivity of groups of two or more workers picking together. The regression coefficient of this interaction term was larger than its standard error. However, none of the variables analyzed in this study were found to have relationships to apple picking rates which differed significantly at the 0.05 level for the two subgroups of worker units based on the size of the unit.

Several variables analyzed in this study displayed a tendency toward differential predictability with respect to the two subgroups of workers identified in this study on the basis of residence. The picking rates of workers over 50 years old were reduced farther below those of workers 26-50 years old if the older workers were residents of Michigan than if they were nonresidents. The productivity of female worker units was lowered less, below that of male worker units, if the females were Michigan residents than if they were from other states. For Michigan residents, the reduction in picking rates resulting from having less than two years of apple picking experience was less than it was for nonresidents. The productivity of Michigan residents was increased more by the practice of making no bonus payment than was the productivity of nonresidents by this practice. The last variable tending to display a tendency toward differential predictability with respect to worker unit residence was tree spread. An increase in tree spread caused less of a reduction in the picking rates of Michigan residents than the same increase caused in the productivity of nonresidents. These tendencies toward differential predictability with respect to the residence variable are indicated by the relative magnitudes of the regression coefficients of the interaction terms representing the above situations compared to the standard errors of these coefficients. The regression coefficients were larger than their standard errors in all cases.

In addition to revealing several variables which tended to display differential predictability, the analysis of worker unit residence subgroups also indicated that nonresident units consistently picked more bushels of apples per hour than Michigan residents. Non-residents were found to have faster picking rates than residents in all situations in which the picking rates of these two subgroups could be compared in this analysis.

The age subgroup analysis did not indicate that any variables had significantly different relationships at the 0.05 level to apple picking rates for the three age subgroups of workers identified in this study. However, four situations were identified in the age subgroup analysis in which the relative picking rates of workers in different age groups were not the same as they were when the age variable was analyzed without interaction terms.

Workers in the 26-50 year-old category had slower picking rates than workers in either of the other two age subgroups when all pickers were working in good weather. Workers in the middle age range also had the slowest picking rates among workers who had less than two years of experience picking apples. When only female pickers were being considered, those in the age subgroup over 50 years old had the highest productivity levels. Pickers in the youngest age class had faster picking rates than those in either of the other two age classes when only workers who were Michigan residents were being compared.

There were four situations found in this study in which the relationships between an independent variable and apple picking performance was significantly different at the 0.10 level for the three sex subgroups of workers. Only one of these four variables had consistent relationships to worker productivity in both years studied for the three sex subgroups. Mixed male and female picking units had significantly higher picking rates at the 0.10 level when they received no bonus payments than did all-male units under the same conditions.

In addition to the above situation in which a significant difference was found in the relationships between bonus payment practices and apple picking rates for two sex subgroups, three instances were found in the sex subgroup analysis in which the relative productivities of the sex classes did not agree with the results of the analysis of the sex variable when it was not interacted with any other variables. Picking units which contained both male and female workers picked more bushels of apples per hour than either units containing only males or only females when only workers less than 26 years old were considered. The mixed sex class also had a higher productivity level than the all-male class among colored picking units. When only workers over 50 years old were compared, female workers picked more bushels of apples per hour than either of the other two sex classes.

Colored workers picked significantly more bushels of apples per hour than white pickers at the 0.05 level when differences in the productivity of workers with fewer than two years of apple picking experience were analyzed for worker subgroups based on ethnic origin. No other variable in the model used for the ethnic subgroup analysis had a relationship with apple picking rates which was both consistent and significantly different for the ethnic groups analyzed.

A consistent relationship could not be identified between worker unit ethnic origin and apple picking rates for the two years included in this study when this relationship was analyzed without any interactions between worker ethnic origin and the other variables observed. However, when the productivity of workers was analyzed using the three ethnic groups in interaction terms the different ethnic subgroups were found to have consistent relative picking rates in several situations.

White workers had the slowest picking rates of the three ethnic subgroups in trees with some to moderate pruning. When trees over 18 feet tall were being picked Mexican and Puerto Rican workers picked more bushels of apples per hour than white pickers. Mexican and Puerto Rican picking units also had higher productivity than white picking units among mixed male and female worker units. The analysis of the picking rates of individuals working alone indicated Mexican or Puerto Rican workers to be the fastest pickers in this situation. White pickers had the slowest picking rates among pickers who worked alone and colored pickers displayed picking rates between those of the other two ethnic origins when working alone. Colored pickers had the highest productivity levels of the three ethnic subgroups when only young workers were considered. In this age group the Mexican or Puerto Rican worker units occupied a median position with respect to productivity while white workers picked the fewest bushels of apples per hour of the three ethnic groups. White pickers had the fastest picking rates of the three ethnic subgroups in only one situation--in good weather. They were followed by Mexican or Puerto Rican workers and colored workers in the order of their productivity levels in this situation.

Conclusions

The number of consistent differences found in the relationships between independent variables and worker productivity for the different subgroups of workers analyzed does give some support for a basic assumption made in this study that labor is not homogeneous. These consistent differences also support the theoretical model upon which the analysis of this study is based. There was, however, little support in terms of significant statistical results for the theoretical model used in this study with the possible exception of the worker unit residence subgroup analysis. Even in this case the statistical evidence was not strong although several variables did tend to show differential predictability for worker units in different residence classes.

Further evidence that labor is not homogeneous is provided by the relatively low R^2 obtained for all regression equations even though a relatively large number of independent variables were analyzed. The percent of variation in apple picking rates accounted for by the regression equations may have been low for other reasons, however. Failure to include variables important in explaining variation in productivity as well as misspecification of functional relationships between independent and dependent variables could have lowered the value obtained for R^2.

At least one variable which should, a priori, be related to apple picking speed was not analyzed in this study. The yield of apples on each tree, or each orchard block, being picked by workers was not included in any of the regression models used in analysis because no observations were obtained for this variable in the 1966 data collection process. Inclusion of this variable should account for some year to year and orchard to orchard variation in worker productivity.

More useful results may be obtained in future research of this nature if more careful attention is given to sampling techniques and to measurement procedures. The sampling technique used in this study failed to provide a sufficient number of observations on certain classes of workers in some situations. Stratification of future samples should improve this deficiency. Several variables analyzed in this study were measured subjectively by the individuals gathering data. More careful training of these individuals in making judgment decisions in the evaluation of these variables should provide a more accurate picture of the true relationship between these variables and worker productivity.

The results of the cross validation procedure carried out in this study to check the consistency of relationships between the explanatory variables observed in this study and the productivity of workers picking apples suggest that little faith can be placed in statistical relationships of the kind examined in this study if they are based on a sample from only one time period. The cross validation procedure which requires two separate samples from the same population was not entirely satisfactory, however. The sample data obtained in 1965 and 1966 which were used in cross validation could not be accepted as coming from the same population on the basis of statistical analysis.

Even though few significant statistical results were found in this study, there is evidence to suggest that differential predictability of picking rates did exist for the sample of workers observed in this study. Not all workers responded in the same manner to the various orchard characteristics, management practices, and weather conditions observed in this study. In short, labor is not homogeneous. This finding has implications for individuals interested in labor whether from a research, legislative, or supervisory standpoint.

Social scientists should find the basic model used in this study of value in designing future research projects dealing with people or the labor resource. It could serve as a basis from which to build new models more useful in explaining or predicting human behavior as well as a useful guide in designing future statistical investigations of factors related to the productivity of labor whether they are conducted by psychologists, economists, or other social scientists.

Legislators should be aware of the implications of labor heterogeneity when considering the enactment of legislation regulating labor wage rates. Setting minimum hourly wage rates in an industry above the marginal value product of labor for some individuals can result in their forced withdrawal from the industry. Such minimum wages may be to the benefit of neither the entrepreneurs or the displaced laborers in the industry if suitable alternative employment opportunities are not available. Establishing minimum piece-rates for apple harvesting at an appropriate level can guarantee pickers the opportunity to earn an acceptable wage on an hourly basis without the undesireable consequences of displacing less productive workers.

Labor heterogeneity also has implications for individuals in a position to hire and/or supervise labor. Using the selection of apple pickers as an example, the apple picking rates of individuals or groups may vary considerably from one situation to another. Knowledge of the relationship between working conditions and worker productivity would appear to be a prerequisite to the selection of apple pickers. And if any variation in picking conditions exists within an orchard, worker productivity may be increased by placement of workers to take advantage of differences in worker productivity under various conditions.

The most striking findings of this study with implications for selecting apple pickers will probably not surprise many apple growers. Residence and experience were the worker characteristics which most consistently differentiated between fast and slow pickers. Residents of states other than Michigan consistently out-performed Michigan residents in picking apples. And experienced pickers had higher productivity levels than inexperienced ones in a majority of situations.

The difficulty growers would have in supervising workers to take advantage of the situations in which differential picking rates might be expected would make this practice of questionable usefulness. For example, the results of this study suggest that in a situation where both resident and nonresident labor is being used an aggregate increase in bushels of apples picked per hour would be expected if Michigan residents picked the tree with the widest spread and nonresidents picked the remaining ones. Total harvest labor costs would not be lowered by separating workers in the above manner if harvesting was done on a piece-rate basis, but harvest period length which may be an important consideration should be shortened. However, different piece-rates for residents and nonresidents might have to be established to compensate Michigan residents for working under less favorable conditions and more supervisory time would be required to assure that residents and nonresidents worked in the appropriate trees. A more detailed study of the economic benefits to be expected from such a practice should be made before recommending it to growers.

The results of this study have implications for apple growers in at least one way in addition to picker selection and placement. This is with respect to long-range planning of an orchard and its management. Tree age and tree spread were both found to have a negative relationship to apple picking rates. This relationship should be considered by apple growers when planning the variety and type of trees, i.e., dwarf or standard, to plant in a new orchard and in timing the replacement of an existing orchard. Picking apples to be sold as fresh fruit was a practice found to significantly reduce apple picking speed. Growers should take this effect on worker productivity into consideration when making management decisions with respect to market outlets for apples. These relationships would have an influence on apple harvesting costs if hourly wage rates were being paid, but if piece-rates were paid the timeliness of harvesting would be the important consideration.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

Fisher, Lloyd H. The Harvest Labor Market in California. Cambridge: Harvard University Press, 1953.

Freund, John E. Mathematical Statistics. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962.

Helmstadter, G. D. Principles of Psychological Measurement. New York: Appleton - Century - Crafts, 1964.

Iowa State University Center for Agricultural and Economic Adjustment. Labor Mobility and Population in Agriculture. Ames: Iowa State University Press, 1961.

Johnston, J. Econometric Methods. New York: McGraw-Hill Book Company, Inc., 1963.

Tagiuri, Renato (editor). Research Needs in Executive Selection. Boston: Harvard Graduate School of Business Administration, 1961.

Thorndike, Robert L. Personnel Selection. New York: John Wiley and Sons, Inc., 1949.

Wood, Dorothy Adkins. Test Construction. Columbus, Ohio: Charles E. Merrill Books, Inc., 1961.

Bulletins

Bureau of Employment Security, U. S. Department of Labor, Farm Labor Developments. Washington, D. C.: U. S. Government Printing Office, February, 1968.

Economic Research Service, United States Department of Agriculture. The Hired Farm Working Force of 1968. Agricultural Economic Report No. 164, Washington, D. C.: U. S. Government Printing Office, June 1969.

Jehlik, Paul J. and Ray E. Wakeley, Population Change and Net Migration in the North Central States, 1940-50. Iowa Agricultural Experiment Station Research Bulletin 430, July, 1955.

Metzler, William H., Ralph A. Loomis, and Nelson L. LeRoy, The Farm Labor Situation in Selected States, 1965-1966, Agricultural Economic Report No. 110, Economic Research Service, United States Department of Agriculture. Washington, D. C.: U. S. Government Printing Office, April, 1967.

Articles

Abelson, Robert P. "Sex Differences in Predictability of College Grades," Educational and Psychological Measurement, Vol. XII, 1952, pp. 638-44.

Bowles, Gladys K. "Migration Patterns of the Rural-Farm Population, Thirteen Economic Regions of the United States, 1940-50." Rural Sociology, Vol. 22, 1952, pp. 1-11.

Dunnette, Marvin D. "A Modified Model for Test Validation and Selection Research," Journal of Applied Psychology, Vol. 47 No. 5, 1963, pp. 317-23.

Frederiksen, Norman and S. Donald Melville. "Differential Predictability in the Use of Test Scores," Educational and Psychological Measurement, Vol. XIV, 1954, pp. 647-56.

Frederiksen, Norman and Arthur C. F. Gilbert. "Replication of a Study of Differential Predictability," Educational and Psychological Measurement, Vol. XX, No. 4, 1960, pp. 759-67.

Gallardo, Lloyd L. "Economics of the Demand for Harvest Labor by the Individual Farm Enterprise," Western Economic Journal, Vol. 2, 1963-4, pp. 183-94.

Ghiselli, Edwin E. "Differentiation of Individuals in Terms of Their Predictability," Journal of Applied Psychology, Vol. 40, No. 6, 1956, pp. 374-7.

Griliches, Zvi. "The Demand for Inputs in Agriculture and a Derived Supply Elasticity," Journal of Farm Economics, Vol. XLI, May 1959, pp. 309-22.

Grooms, Robert R. and Norman S. Endler. "The Effect of Anxiety on Academis Achievement," Journal of Educational Psychology, Vol. 51, No. 5, 1960, pp. 299-304.

Pheteplace, W. D., Jr. "Manufacture of Applesauce in the Digestor or Pressure Cooker," Food Industries, Vol. 10, No. 4, p. 194.

Schuh, G. Edward. "An Econometric Investigation of the Market for Hired Labor in Agriculture," Journal of Farm Economics, Vol. XLIV, May 1962, pp. 307-21.

Tomek, William G. "Using Zero-One Variables With Time Series Data in Regression Equations," Journal of Farm Economics, Vol. 45, No. 4, November 1963, pp. 814-22.

Wallace, T. D. and D. M. Hoover. "Income Effects of Innovation: The Case of Labor in Agriculture," Journal of Farm Economics, Vol. 48, May 1966, pp. 325-36.

Public Documents

82nd Congress of the United States of America. U. S. Statutes at Large, 1951. Washington, D. C.: U. S. Government Printing Office, Vol. 65, 1952.

U. S. Bureau of the Census. Census of Agriculture, 1964. Part 13, Michigan. Washington, D. C.: U. S. Government Printing Office, 1967.

1965 Michigan State Legislature, Michigan Public Act 296.

APPENDIX

APPENDIX

Two statistical tests discussed in Chapter III on page 19 require some additional explanation. The first of these is a test for differences between means.

Differences Between Means

A test of the form[1],

$$z = \frac{\bar{x}_1 - \bar{x}_2 - a}{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^{1/2}}$$

was used to test the null hypothesis that the means of the dependent variable (bushels of apples picked per hour per picking unit) for the two years 1965 and 1966 were equal. In the above equation:

$\bar{x}_1$ = sample mean of dependent variable in 1965

$\bar{x}_2$ = sample mean of dependent variable in 1966

s_1 = sample standard deviation of dependent variable in 1965

s_2 = sample standard deviation of dependent variable in 1966

n_1 = number of observations on dependent variable in 1965

n_2 = number of observations on dependent variable in 1966

a = the hypothesized difference between the means of the dependent variable in the two years 1965 and 1966, a = 0 for the null hypothesis

[1]John E. Freund, Mathematical Statistics, Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962, pp. 266-9.

The null hypothesis $H_0: \mu_1 - \mu_2 = 0$ was tested against the alternative hypothesis $H_A: \mu_1 - \mu_2 \neq 0$

Where:

μ_1 = population mean of dependent variable in 1965

μ_2 = population mean of the dependent variable in 1966

Using the appropriate values calculated from the sample data for the two years, z was calculated as follows:

$$z = \frac{9.6134 - 8.9738}{\left(\frac{(4.3807)^2}{3982} + \frac{(3.2904)^2}{647}\right)^{1/2}}$$

$$z = \frac{.6396}{\left(\frac{19.1905}{3982} + \frac{10.8267}{647}\right)^{1/2}}$$

$$z = \frac{.6396}{(.0048 + .0167)^{1/2}} = \frac{.6396}{(.0215)^{1/2}}$$

$$z = \frac{.6396}{.1466} = 4.3629$$

The null hypothesis $H_0: \mu_1 - \mu_2 = 0$ must be rejected since $z = 4.3629$ is greater than the appropriate value from a t-table at all commonly accepted levels of significance. For example, $z = 4.3629$ is greater than the t-table value of 2.576 for the 99 percent level of confidence for large samples.

Equality Between Coefficients in Two Relations

The second statistical test discussed on page 19 is a test of equality between coefficients in two relations taken from Johnston.[2]

---

[2] J. Johnston, <u>Econometric Methods</u>, New York: McGraw-Hill Book Company, Inc., 1963, pp. 136-7.

This test is used to determine whether the observations taken in 1966 came from the same relationship as those taken in 1965. Let $Y_1 = X_1 \beta_1 + u_1$ represent the relationship between the dependent variable and k independent variables in 1965. Let $Y_2 = X_2 \beta_2 + u_2$ represent the same relationship for 1966.

Y_1 represents the observations taken on the dependent variable in 1965 and is of order n x 1. Observations taken on the independent variables in 1965 are represented by X_1 which is of order n x k. β_1 which is order k x 1 represents the independent variables observed in 1965. The disturbance (or error) term in the relationship for 1965 is represented by u_1 which is of order n x 1.

Y_2 is of order m x 1 and represents the observations taken on the dependent variable in 1966. Observations taken on the independent variables in 1966 are represented by X_2 which is of order m x k. β_2 is of the same order as β_1 and represents the same independent variables as did β_1. The disturbance term in the relationship for 1966 is represented by u_2 which is of order m x 1.

Assuming that u_1 and u_2 both have the same normal distribution with variance - covariance[3] matrix $\sigma^2 I$ and that m > k; the hypothesis $\beta_1 = \beta_2 = \beta$ may be tested by computing the F ratio,[4]

$$F = \frac{\frac{Q_3}{k}}{\frac{Q_2}{(m + n - 2k)}}$$

[3]Where I is an identity matrix and σ^2 is a scalar.

[4]For a discussion of the development of this test see Econometric Methods, _op_. _cit_., pp. 136-7.

with degrees of freedom (k, m + n - 2k). To compute the value of this F ratio the following steps are necessary:

1. Combine the 1965 and 1966 data and compute the least-squares estimates of the regression coefficients and then obtain the sum of squared residuals, Q_1.
2. Compute the least-squares estimates of the regression coefficients for each year's data separately and obtain the sum of squared residuals for each year separately.
3. Total the two sums of squared residuals for the two years to obtain Q_2.
4. Compute $Q_3 = Q_1 - Q_2$.
5. Compute F as defined above.
6. If $F > F_{\alpha,k,m+n-2k}$ reject the hypothesis $\beta_1 = \beta_2 = \beta$.

The calculation of F using the appropriate values for the two relationships observed in this study is as follows:

$Q_1 = 69,419.3928$

$Q_2 = 61,819.1060 + 5,252.4898 = 67,071.5958$

$Q_3 = 69,419.3928 - 67,071.4948 = 2,347.7970$

$n = 3982$

$m = 647$

$k = 24$

$$F = \frac{\dfrac{2,347.7970}{24}}{\dfrac{67,071.5958}{647 + 3982 - 2(24)}}$$

$$F = \frac{\dfrac{2,347.7970}{24}}{\dfrac{67,071.5958}{4581}}$$

$$F = \frac{97.8248}{14.6412} = 6.68$$

Since $F = 6.68$ is greater than $F_{.01,24,\infty} = 1.79$ the hypothesis that $\beta_1 = \beta_2 = \beta$ must be rejected at the one percent level of significance.