To the Graduate Council:

I am submitting herewith a thesis written by Stanley Edward Pendlum entitled "Technical, Price, and Economic Efficiency Measures in the Tennessee Meat Packing and Processing Industry." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Irving Dubov

Irving Dubov, Major Professor

We have read this thesis
and recommend its acceptance:

Billy J. Travers

Sam K. Winfree

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

Ag-VetMed
Thesis
76
P349
cop.2

TECHNICAL, PRICE, AND ECONOMIC EFFICIENCY MEASURES IN THE TENNESSEE MEAT PACKING AND PROCESSING INDUSTRY

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Stanley Edward Pendlum

December 1976

1306025

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. Irving Dubov for his assistance in carrying out the analyses reported in the following chapters. Appreciation is also extended to Dr. Sam Winfree and Dr. Billy J. Trevena for counsel and suggestions throughout this study.

He would also like to express his debt of gratitude to Dr. Joe A. Martin and the Department of Agricultural Economics and Rural Sociology for financial assistance during the course of graduate studies.

Lastly, the author would like to thank his parents for their direction and encouragement during the educational process.

ABSTRACT

The purpose of this study was (1) to determine the changes that have occurred in expenditures for energy sources, petrochemical based materials, and related items used in the Tennessee meat packing and processing industry between 1974 and 1975, (2) to determine the effect of these changes on relative costs, efficiencies, and operating procedures and programs, and (3) to determine if a significant change occurred in the minimum average cost of production between 1974 and 1975.

Price-quantity data for 40 packer level units were obtained with an industry questionnaire. Variables selected for analysis included physical amounts and expenditures for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials. These five inputs were hypothesized to be key factors in estimating the efficiency of production in the meat packing and processing industry.

The Farrell efficiency model was used to estimate technical, price, and economic efficiency measures for the slaughterers under study in 1974 and 1975. Input-output ratios for the operating units were analyzed as the linear programming algorithm iterated through the 40 linear programming problems.

Two analyses were used in the study. The first, a composite analysis, assumed that no differences existed in the scale and production characteristics of custom and commercial slaughterers. Efficiency measures were found for the 40 observations in an algorithm containing

input-output ratios of both custom and commercial slaughterers. A second analysis classified custom and commercial slaughterers into two subsamples based on the type of license held by the firm. Technical, price, and economic efficiency ratings were found for each observation relative to other slaughterers within the same slaughtering classification.

Technical and price efficiency ratings were found for each observation in the sample, relative to a postulated standard of perfect efficiency set forth by the efficient unit isoquant (EUI). Observations with a maximum objective function value equal to one, formed the convex closure of the EUI. As such, they demonstrated the "best" performance of the sampled observations in their adjustments to factor proportions and factor prices.

Economic efficiency for the 40 observations were formed as the product of their respective technical and price efficiency ratings, found with the linear programming algorithms. This measure was equivalent to the inverse ratio of average cost of production. A firm that was perfectly efficient, both technically and with respect to factor prices, also was 100 percent economically efficient. Such a firm could be assumed to have the minimum average costs of production of the sampled observations, with respect to the five inputs included in the analysis.

Results of the Mann-Whitney statistical test indicated that a significant increase occurred in the average cost of production for commercial slaughterers between 1974 and 1975.

The Kruskal-Wallis rank-sum test indicated that a significant difference existed in the average cost of production for custom and commercial slaughterers in 1975. The lower average cost of production for custom slaughterers suggested that these slaughterers as a group were able to respond more readily to increased costs for inputs to production.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
	The Problem	1
	Objectives of This Study	5
	Research Procedure	5
	Description of the Study Area	6
II.	BACKGROUND AND PROCEDURE	10
III.	THEORETICAL AND COMPUTATIONAL FRAMEWORK	21
IV.	DATA AND METHODOLOGY	35
	The Theoretical Model	35
	Selection of Variables	37
	Methods of Analysis	39
V.	RESULTS AND DISCUSSION	43
	Changes in Expenditures for Inputs	43
	Analysis of Efficiency Indexes	46
	The Composite Analysis, 1974 and 1975	48
	The Split Analysis, 1974 and 1975	53
VI.	SUMMARY AND CONCLUSIONS	61
	Review of the Approach	61
	Conclusions	62
	Implications for Operating Procedures and Programs	64

CHAPTER PAGE

BIBLIOGRAPHY 65

APPENDICES 69

Appendix A 70

Appendix B 75

Appendix C 79

Appendix D 82

VITA 83

LIST OF TABLES

TABLE		PAGE
1.1	Energy Used by Major Food Processing Industries, by SIC Code, Selected Periods	3
1.2	Energy Use Patterns by SIC Code and Type of Energy Used for Selected Industries, 1971	4
1.3	Number of Plants, by Size, Slaughtering Meat in Tennessee in 1974	8
5.1	Expenditures for Hired Labor, Electricity, Water and Sewage Service, Natural Gas, and Supplies and Cleaning Materials Per $1000 Gross Sales, 1974 and 1975	44
5.2	Technical Efficiency (TE), Price Efficiency (PE), Economic Efficiency (EE), and Level of Output for 1974	49
5.3	Technical Efficiency (TE), Price Efficiency (PE), Economic Efficiency (EE), and Level of Output for 1975	50
5.4	Frequencies and Average Efficiency of Measures of Technical Efficiency (TE), Price Efficiency (PE), and Economic Efficiency (EE), Gross Sales Used as a Measure of Output, 1974 and 1975	51
5.5	Technical Efficiency (TE), Price Efficiency (PE), Economic Efficiency (EE), and Level of Output for Custom Slaughterers, 1974 and 1975	54
5.6	Technical Efficiency (TE), Price Efficiency (PE), Economic Efficiency (EE), and Level of Output for Commercial Slaughterers, 1974 and 1975	55

TABLE PAGE

5.7 Frequencies and Average Efficiency of Measures of Technical Efficiency (TE), Price Efficiency (PE), and Economic Efficiency (EE), Custom Slaughterers, 1974 and 1975 . . . 56

5.8 Frequencies and Average Efficiency of Measures of Technical Efficiency (TE), Price Efficiency (PE), and Economic Efficiency (EE), Commercial Slaughterers, 1974 and 1975 . 57

A.1 The Mann-Whitney Rank-Sum Test for a Change in the Mean Economic Efficiency Measure, Composite Analysis, 1974 and 1975 72

A.2 The Mann-Whitney Rank-Sum Test for a Change in the Mean Economic Efficiency Measure, Custom Slaughterers, 1974 and 1975 73

A.3 The Mann-Whitney Rank-Sum Test for a Change in the Mean Economic Efficiency Measure, Commercial Slaughterers, 1974 and 1975 74

B.1 Kruskal-Wallis Rank-Sum Test for a Significant Difference in the Mean Economic Efficiency Measure for Custom and Commercial Slaughterers, 1974 77

B.2 Kruskal-Wallis Rank-Sum Test for a Significant Difference in the Mean Economic Efficiency Measure for Custom and Commercial Slaughterers, 1975 78

C.1 Reported Expenditures for Hired Labor, Electricity, Water and Sewage Service, Natural Gas, and Supplies and Cleaning Materials, Gross Sales Used as a Measure of Output, 1974 . 80

TABLE PAGE

C-2 Reported Expenditures for Hired Labor, Electricity, Water and Sewage Service, Natural Gas, and Supplies and Cleaning Materials, Gross Sales Used as a Measure of Output, 1975 81

LIST OF FIGURES

FIGURE		PAGE
3.1	Hypothetical Isoquant Map: The Case of a Linear Homogenous Production Function	23
3.2	Hypothetical Unit Isoquant: The Case of a Linear Homogenous Production Function	25
3.3	Hypothetical Isoquant Map with Relevant Isocost Lines Superimposed	26
3.4	Illustration of Technical, Price, and Economic Efficiency .	29
3.5	Hypothetical Efficient Unit Isoquant Approximated by Fitting an Envelope from Below to the Scatter of Observations . .	32
3.6	Hypothetical Example of the "Pessimistic" Estimate of the Efficient Unit Isoquant--Two Factor Case	33

CHAPTER I

INTRODUCTION

Recent fundamental and far-reaching changes have occurred in the supply-price situation for alternative energy sources, petrochemicals, and related items in all parts of the United States. These changes affect every aspect of economic activity, including all segments of the agricultural industries. The meat packing and processing industry is one such segment. Relative costs, factor mixes, and prices at all levels of the production/marketing system are influenced--from the farm to the retail meat counter. The groups affected by these changes include livestock producers, marketing agencies, packers and processors, wholesalers, retailers, and ultimately the consumer. Members of each group in Tennessee need reliable information regarding the adjustments possible within the respective ranges of operating procedures, interests, and concerns. Individuals and agencies concerned with formulating policies affecting the livestock production, packing, and distribution industries also need this information.

I. THE PROBLEM

The extensive processing, handling, and transportation activities involved in the manufacturing and merchandising of meat and meat products have become highly dependent on energy and petrochemical based materials.

Of the major food processing industries, meat packing is the largest single consumer of energy items (Table 1.1). Energy use in the meat packing industry reached a record high in 1971 when 110,000 billion Btu's of energy were consumed. Consumption declined slightly to 99,300 billion Btu's of energy in 1973.

Energy use patterns also vary between industries with respect to the type of energy used (Table 1.2). In 1971, consumption of natural gas and purchased electricity accounted for 48.8 percent and 30.5 percent, respectively, of the total energy used (in Btu's) in the meat packing industry. Propane gas, coal, middle distillates, residual fuel oils, and other petroleum based products accounted for the remaining 20.7 percent of consumed energy items.

As supplies of fossil fuel resources decline, costs of energy and petrochemical based materials used in the meat packing industry will increase. According to Pimental et al., energy costs are expected to double or triple in the next decade;[1] and others have projected a fivefold increase by the turn of the century.[2,3]

The problem this study examined was the changes, if any, in technical, price, and economic efficiency in the Tennessee meat packing

---

[1] Science, vol. 177, p. 875, (1972), cited by Pimental et al., "Food Production and the Energy Crisis," Science, November 2, 1972, p. 443.

[2] Futures, vol. 4, p. 331, (1972), cited by Pimental et al., ibid., p. 443.

[3] Report to Program on Policies for Science and Technology in Developing Nations (University of Strathclyde, Glasgow, 1972), cited by Pimental et al., ibid., p. 443.

Table 1.1 Energy used by major food processing industries, by SIC code, selected periods

Industry	SIC code No.	1954	1967	1971	1973
ENERGY INPUT			-billions of Btu's-		
Meat packing	2011	93,596	78,929	110,000	99,300
Sausage and other prepared meat	2013	10,557	16,101	27,900	25,500
Fluid milk	2026	6,615	64,121	81,200	78,500
Canned fruits and vegetables	2033	37,268	36,516	50,400	52,500
Frozen fruits and vegetables	2037	8,202	21,340	54,200	62,200
Animal feeds	2042	9,401	46,897	83,900	86,500
Wet corn milling	2046	50,288	60,442	72,200	83,700
Cane sugar refining	2062	33,149	31,254	44,700	44,600
Beet sugar refining	2063	39,149	72,407	75,400	76,600
Malt beverages	2082	41,502	40,649	68,700	75,400
Animal and marine fats and oils	2094	3	27,670	26,400	24,400
TOTAL		329,855	496,326	695,000	708,340

Source: John H. Berry, "The Energy Problem and Agricultural Production," Western Agricultural Economics Association, Proceedings, 1974, Moscow, Idaho, July 24-26, 1974, p. 198

Table 1.2 Energy use patterns by SIC code and type of energy used for selected industries, 1971.

Industry	SIC Code Number	Propane	Middle distillates	Residual Fuel Oils	Other Petroleum Products	Coal	Natural Gas	Other Fuels	Purchased Electricity	Total
					percent					
Meat packing	2011	2.1	3.3	5.2	0.2	10.1	48.8	- -	30.5	100
Sausage and processed meat	2013	1.2	8.1	3.7	0.2	0.9	48.4	- -	37.6	100
Fluid milk	2026	1.8	8.1	4.1	2.1	3.3	34.9	- -	45.8	100
Canned fruits and vegetables	2033	2.9	0.9	6.8	- -	3.4	69.6	- -	16.4	100
Frozen fruits and vegetables	2037	1.0	0.5	2.8	- -	3.6	42.1	- -	50.2	100
Prepared animal feeds	2042	3.0	3.5	2.4	1.1	0.3	53.4	- -	36.5	100
Wet corn milling	2046	0.1	4.5	1.3	- -	35.6	44.2	- -	14.1	100
Cane sugar refining	2062	- -	0.2	30.2	- -	- -	68.9	- -	0.6	100
Beet sugar refining	2063	- -	0.1	2.4	- -	25.6	66.4	4.0	1.4	100
Malt beverage	2082	0.7	5.3	11.5	- -	7.0	38.3	- -	37.3	100
Animal and marine fats and oils	2094	0.8	6.6	9.1	0.7	0.8	65.9	- -	15.9	100
Manufactured ice	2097	- -	3.5	- -	- -	- -	11.5	- -	84.9	100
Percentage total		1.3	3.6	6.2	0.5	9.7	50.6	0.5	27.6	100

Source: John H. Berry, "The Energy Problem and Agricultural Production," Western Agricultural Economics Association, Proceedings, 1974, Moscow, Idaho, July 24-26, 1974, pp. 199.

industry that occurred between 1974 and 1975 in response to increased prices for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials. Efficiency measures were calculated from firm cost data for selected energy sources, petrochemical based supplies, and related items. The inputs selected for study were hypothesized to be key factors in estimating the efficiency of production for the individual firms observed.

II. OBJECTIVES OF THIS STUDY

The specific objectives of this study were:

1. To determine the changes that have occurred in expenditures for energy sources, petrochemical based materials, and related items used in custom and commercial slaughtering plants in the Tennessee meat packing and processing industry between 1974 and 1975.

2. To determine the effects of these changes on relative costs, efficiencies, and operating procedures and programs.

3. To determine if a significant change occurred in the minimum average cost of production between 1974 and 1975.

III. RESEARCH PROCEDURE

The general procedure involved analysis of data gathered from operating units at the packer level. Only those firms actually engaged in slaughtering activities were included in the survey. Firms that were strictly processors were excluded, in order to define an industry whose firms had similar input requirements and produced a more or less homogenous output.

Data collected and analyzed relative to Objective 1 included costs of electricity, water and sewage service, natural gas, hired labor, and supplies and cleaning materials.

In respect to Objective 2, data gathered to accomplish Objective 1 were used to calculate technical, price, and economic efficiency estimates to reflect any adjustments in factor utilization or to changes in factor prices for the selected years. A Farrell efficiency model[4] was used to accomplish this objective.

Objective 3 was accomplished by observing 1974 and 1975 economic efficiency measures formed as the product of technical and price efficiency, found as a part of Objective 2. The economic efficiency measures were equivalent to the inverse ratio of average cost of production.[5]

IV. DESCRIPTION OF THE STUDY AREA

The segment of the industry sampled in this study was the custom slaughtering and small-to-intermediate commercial slaughtering plants in Tennessee. The difficulty of obtaining data from the larger plants, especially those owned by multi-plant corporations precluded their inclusion in the coverage of this study.

Custom slaughterers and small-to-intermediate commercial plants accounted for 9.3 percent of the total poundage of all cattle and 11.9

---

[4]M. J. Farrell, "Measurement of Productive Efficiency," Journal of Royal Statistical Society, Series A, Part III, 120:253-281.

[5]R. G. Bressler, "Measurement of Productive Efficiency," Western Farm Economics Association, 1966 Proceedings (Pullman, Washington, 1967), p. 130.

percent of the hogs killed in Tennessee in 1970.[6] This amounted to approximately 514,000 head of cattle and 2,892,000 head of hogs that were slaughtered and processed by the segment of the industry under study.[7]

In 1974, there were 86 livestock slaughtering establishments in Tennessee (Table 1.3). Twelve plants were regulated by federal inspection, and the remaining 74 plants fell under state inspection regulations. Forty-one of the state regulated plants were engaged in custom slaughtering. The remaining 33 plants slaughtered animals for movement into commercial trade channels.

In October 1975, all slaughtering establishments came under the jurisdiction of federal livestock and meat inspectors. Custom slaughterers also came under federal inspection standards, but were subject to inspection standards for sanitation only.

The custom slaughterers covered by the survey slaughtered and processed animals for a fee as the major income source. Such plants were required to comply with federal meat inspection sanitation standards, but individual animals were not subject to antemortem or postmortem inspection. These establishments operated primarily to provide a service to individuals desiring meat and meat products slaughtered for home consumption.

---

[6]Robert John Hopkins, "The Wholesome Meat Act and the Tennessee Livestock-Meat Industry," (unpublished Ph.D. Dissertation, University of Tennessee, Knoxville, 1972), p. 19.

[7]Ibid.

Table 1.3 Number of plants, by size, slaughtering meat in Tennessee in 1974

Type and size of plant	Number of plants
Slaughtering plants	
State inspected	
Slaughtering over 4,000 animals per year	7
Slaughtering 1,000 to 4,000 animals per year	16
Slaughtering less than 1,000 animals per year	10
Custom slaughtering	41
Federally inspected	
Slaughtering livestock, all sizes	12
Total	86

Source: Tennessee Department of Agriculture, Directory 1974, Division of Food and Drugs, Nashville, Tennessee, 1974.

The small-to-intermediate commercial slaughterers in the survey, slaughtered and processed animals for resale to restaurants, hotels, grocery stores, institutional markets, and the general public. Established routes were often maintained for the convenience of steady customers.

CHAPTER II

BACKGROUND AND PROCEDURE

R. G. Bressler defined efficiency as " . . . a relative concept by which two situations may be compared, or possibly, by which any given situation may be rated relative to some ideal. More specifically, efficiency will be measured in terms of relations between input-output ratios."[1] An efficient organization was defined as:

> . . . one that yields a greater output for a given input than does some alternative organization or, conversely, that requires a smaller input to obtain a given output. It follows, of course, that the most efficient organization will be that alternative which maximizes the output for a given input or minimizes the input for a given output.[2]

Although sounding rather straight-forward, application of this efficiency definition was not as simple as it first appeared. Often multiple inputs and outputs were present in the productive process. This required partial measurements which involved balancing off of one factor or product against another factor or product to determine efficient processes. Indices of technical efficiency were constructed in which a weighted average of inputs were compared to output. In this approach, it was assumed that the marginal increment of product per dollar of factor expenditures was equal for all factors involved. Such

---

[1] R. G. Bressler, "Efficiency in the Production of Marketing Services," Economic Efficiency Series Paper No. 6, Social Science Research Council Project in Agricultural Economics (Chicago: University of Chicago, 1950), p. 1.

[2] Ibid., pp. 1-2.

a weighting index suffered from the usual problem of assigning weights to heterogenous inputs in order to determine the level of output representing an efficient organization.

Review of Literature

In 1957, Farrell discussed problems of measuring productive efficiency of a firm or industry.[3] His purpose was to provide a satisfactory measure of productive efficiency that took account of all inputs, and yet avoided index number problems. A model was developed and illustrated with an application to agricultural production in the United States.

Farrell initially described a simple case using two factors, a single product, and constant returns to scale. These restrictions were relaxed later to include increasing and decreasing returns to scale for cases involving multiple inputs and outputs.

Farrell's model presented three measures of firm and industry efficiency. The first was technical efficiency, which measured each firm's input combination relative to the standard of efficiency given by an efficient unit isoquant. This standard defined technical efficiency in terms of a line or facet that traced out the minimum combinations of inputs required to produce one unit of output. All firms whose input/output performances were on the efficient unit isoquant were rated as 100 percent technically efficient. Those whose inputs per unit of output were above and to the right of this line or facet were less than 100 percent efficient, with the degree of technical

---

[3]Farrell, op. cit.

efficiency being indirectly related to proximity to the efficient unit isoquant.

A second measure, price efficiency, was obtained by relating the input combination of a firm relative to the input combination where the minimum isocost line was just tangent to the efficient unit isoquant. In the case where n inputs were used in production of a single output under constant returns to scale, the efficient unit isoquant was approximated by the points $(x_1/X, x_2/X, \ldots . x_n/X)$ where X was output and $x_1, x_2, \ldots . x_n$ were inputs. Points at infinity on each of the n axes were added to form the convex closure of the efficient unit isoquant. The point of tangency between the isocost line and the convex efficient unit isoquant was rated 100 percent price efficient. This was the standard by which a firm's success in adjusting to factor price relations was measured.

A third measure, economic efficiency, was equal to the product of the technical and price efficiencies of a firm. This overall efficiency measure was equivalent to the inverse ratio of average cost of production. Firms with the lowest observed average cost would be assigned an index of 100 percent economic efficiency.

Farrell and Fieldhouse,[4] in 1962, expanded the framework to include situations with both increasing and decreasing returns to scale. They proposed two methods of determining the efficient unit isoquant

---

[4]M. J. Farrell, and M. Fieldhouse, "Estimating Efficient Production Functions Under Increasing Returns to Scale," Journal of Royal Statistical Society, Series A, Part II, 129:252-268, 1962.

when returns to scale were not constant. The techniques were later illustrated with an application to British farms.

The first method involved dividing observations into groups of firms having roughly equal output and defining an efficient unit isoquant for each. The underlying assumption was that returns to scale were constant within each group.

A second, or "overall method," required a production function that included scale as an added variable. The scale variable added a third dimension, perpendicular to the X and Y axes, in the two-input, single-output production situation. In this manner, the production function could be specified in terms of an efficient unit isosurface (EUIS). This surface was analogous to the efficient unit isoquant (EUI) in the case of constant returns to scale. Efficiency measures were found for a given firm by orthogonal projections from the EUIS to the scale line. Each firm was rated relative to those firms in the sample that utilized the same factor combinations and was in the same scale activity.

Bressler reviewed the work of Farrell in 1966.[5] He pointed out the relative merits of this model compared to the conventional production function approach to efficiency measures. The efficient unit isoquant was identified as the crucial element in computing relative efficiency measures for individual observations. The effect of scale economies on the estimate of an efficient unit isoquant was also discussed. Bressler concluded that the Farrell model provided a legitimate estimate of

---

[5]Bressler, op. cit., p. 130.

efficient organizations, while regression techniques, such as the Cobb-Douglas approach, provided average approximations of efficiency. Bressler also pointed out that the economic efficiency measures proposed by Farrell were equivalent to the inverse ratios of average cost.

Boles outlined the computational techniques to use in computing efficiency measures specified in the Farrell model.[6] A system of computer routines were developed and tested to handle three types of problems: single product with constant returns to scale assumed, multiple products with constant returns to scale assumed, and single product with economies to scale. The program and subroutines were written in FORTRAN and designed specifically for use with the IBM 1130 system.

Seitz applied the Farrell model to data from a sample of steam-generating plants for years 1948-1952 and 1958-1961.[7] Efficiency measures were computed for 81 sample plants using a three-factor, (labor, fuel, investment) single output (power in kilowatt hours) analysis. In his study, Seitz attempted to determine the relation of technical efficiency to non-quantifiable variables such as location and type of construction. A similar analysis was made that related technical efficiency ratings to the type of fuel used by each plant.

Sitorus, in 1966, reported on an eight-factor, single-output analysis of 58 agricultural municipalities in the Luzon Province of the

---

[6]James N. Boles, "The 1130 Farrell Efficiency System-Multiple Products, Multiple Factors," Giannini Foundation of Agricultural Economics (University of California, February, 1971).

[7]Wesley D. Seitz, "Efficiency Measures for Steam-Electric Generating Plants," Western Farm Economics Association, 1966 Proceedings (Pullman, Washington, 1967), pp. 143-151.

Republic of the Philippines.[8] Inputs included in the analysis were: (1) irrigated land, (2) non-irrigated land, (3) available labor supply, (4) number of working animals, (5) number of plows, (6) number of harrows, (7) number of carts, and (8) number of sprayers. Output was measured as the total value of all farm crop production at local prices. Sitorus attempted to determine the factors affecting efficiency in the use of inputs of production, and the usefulness of socio-economic factors as indicators of redundancy in the use of labor. Particular attention was directed at the land tenure system, the institutional structure of the transportation system, marketing system, pricing policies, and the population growth rate.

In 1969, Timmer presented an approach to the integration of the Farrell efficiency concept with the conventional context of economic theory.[9] He used a six-factor, single-output analysis for the 48 contiguous States with observations for 1960-1967 in his illustration of allocative efficiency. Inputs included in the analysis were: (1) labor, (2) capital, (3) land and buildings, (4) fertilizer, (5) livestock, and (6) seeds and miscellaneous. Output was measured as gross agricultural output for each of the states in the study.

---

[8] Bistok L. Sitorus, "Productive Efficiency and Redundant Factors of Production in Traditional Agriculture of Underdeveloped Countries," Western Farm Economics Association, 1966 Proceedings (Pullman, Washington, 1967), pp. 153-158.

[9] C. Peter Timmer, "On Measuring Technical Efficiency," Food Research Institute Studies in Agricultural Economics, Trade and Development (Stanford, California, 9:97-171, 1970).

O'Conner and Hammonds,[10] in 1975, presented an approach to measuring economic efficiency that differed from the Farrell and Farrell-Fieldhouse formulations. Their unit output price (UOP) profit model was based on an earlier model developed by Lau and Yotopoulos,[11] and incorporated both input and output-price levels. This model consisted of a single profit equation in which profit level was expressed as a function of fixed input quantities and variable input prices. In addition, a derived demand function was found for each independent variable in the profit model. Each equation was estimated by ordinary least squares since all independent variables were determined outside the model for price-taking firms. With the assumptions that all firms were profit maximizers and price takers, the UOP profit model was estimated without being concerned with the underlying production function.

O'Conner and Hammonds investigated the relative technical, price, and economic efficiencies for four groups of retail meat departments. Their findings, using the UOP profit model, were compared to the results obtained with a Farrell-Fieldhouse model for the same four groups of meat departments. O'Conner and Hammonds concluded that the UOP profit model was superior as a test for measuring efficiency since this approach was void of scale bias present in the Farrell-Fieldhouse model. In

---

[10] C. W. O'Conner and T. M. Hammonds, "Measurement of the Economic Efficiency of Central-Fabrication versus Carcass-Meat Handling Systems," American Journal of Agricultural Economics, 57:665-675, 1975.

[11] Lawrence J. Lau, and Pan A. Yotopoulos, " A Test for Relative Economic Efficiency: Some Further Results," American Economic Review, 63:213-223, 1973.

addition, the Farrell-Fieldhouse model provided none of the statistical measures of goodness-of-fit found in the least-squares technique employed in the UOP profit model.

Aigner and Chu,[12] in 1966, took issue with Farrell's approach to efficiency measures. They argued that many types of production cannot be described in a Farrell framework. In particular, they noted that some production functions may not conform to the Law of Variable Proportions, thus yielding a production function that violated Farrell's convexity assumption. This assumption eliminated that portion of the production function over which output decreased with increased utilization of factors of production. However, this criticism was of little consequence, as the stage of production was irrational when decreasing returns occurred with additional units of any input. They proposed, instead, mathematical or quadratic programming using cross-sectional data to generate the industry production function. This would require no presumptions about returns to scale. In this manner, they approximated a production surface one would be unable to obtain using the Farrell technique.

Nerlove, in 1965, also questioned the applicability of Farrell's method of efficiency measures.[13] His criticism was directed at Farrell's assumption of constant returns to scale. He rejected the Farrell

---

[12]D. J. Aigner, and S. F. Chu, "On Estimating the Industry Production Function," American Economic Review, 58:826-839, 1968.

[13]Marc Nerlove, Estimation and Identification of Cobb-Douglas Production Functions (Chicago: Rand McNally and Company, 1965).

procedure in favor of a Cobb-Douglas specification that was not restricted to situations exhibiting constant or increasing returns to scale.

Efficiency in the Livestock Slaughtering Industry

Sanders, Frazier and Padgett, in 1964, completed a study of the economic efficiencies within livestock slaughtering plants.[14] Four plants with somewhat different operating procedures were selected for intensive study in an attempt to determine some of the factors that might contribute to the efficiency of the individual plant. Particular emphasis was placed on labor and the various tasks performed by each worker. However, other cost items such as electricity, water and sewage, fuel, supplies, office requirements, and overhead costs also were included in the study.

Their conclusions indicated that the major factors affecting the efficiency of livestock slaughtering operations were: (1) size and layout of plants, (2) size and type of equipment in use, (3) number of workers assigned to the slaughtering operation, (4) crew balance, (5) work methods and motion patterns of individual workers, (6) differentials in labor costs, and (7) type of meat inspection practice used.

A recent study by John Morrell and Company was specifically aimed at efficient use of energy items in the livestock slaughtering industry.[15] Their study used a "total energy" concept in which each utility was analyzed in respect to interdependence with every other

---

[14] Adolph Sanders, T. L. Frazier, and J. H. Padgett, "An Appraisal of Economic Efficiencies Within Livestock Slaughtering Plants," Georgia Agricultural Experiment Station Bulletin, N. S. 122, 1964.

[15] W. Lloyd, and E. J. Opryszek, "How to Save Energy in a Meat Plant," Meat Industry, vol. 22, No. 2 (February, 1976), pp. 25-27.

utility. For example, fuel was analyzed with respect to water, electricity, and refrigeration.[16] The purpose of the study was to determine the input mix resulting in the lowest total energy consumption.

Swift and Company also conducted a major energy efficiency study at their plant in East St. Louis, Illinois.[17] Energy saving steps included insulation of steam and hot water lines, shutting down a second boiler that was used only occasionally, reducing water pressure and temperature, and turning off unneeded lighting. Early results indicated that a total savings of 69,000 Btu of energy was possible for the 31-week period of the study. This represented a 7.5 percent decrease in energy consumption over the same period in the previous year.

A study prepared for the Federal Energy Administration by Foster D. Snell, Inc., found a declining use of Btu's per pound of dressed weight in 2000 slaughtering/processing plants in the United States.[18] The Snell study suggested that the average plant could realize savings in energy costs amounting to 32 percent over the long run: 13 percent would accrue within six months, 6 percent within eighteen months, and an additional 13 percent after the initial eighteen months.

Results of another Federal Energy Administration study by Development Planning and Research Associates, Inc., Manhattan, Kansas, concluded that the limit in savings for energy items was about 10 percent

---

[16]Refrigeration was considered a separate utility for purposes of this study.

[17]Lloyd and Opryszek, op. cit.

[18]Meat Industry, "Conserving Energy," vol. 21, No. 4 (April, 1975), pp. 20-22.

for the long run.[19] Such an estimate was based on the fact that much of the meat packing operation was within a fairly rigid framework of union and USDA regulations.

---

[19] Ibid.

CHAPTER III

THEORETICAL AND COMPUTATIONAL FRAMEWORK

Farrell's method of estimating technical, price, and economic efficiency was based on microeconomic principles. His approach grew out of dissatisfaction with the conventional approach to efficiency that dealt with only a single factor of production. This single-factor analysis was based on simple input-output ratios, such as labor used per unit of product or capital requirements per unit of product. The inherent difficulty with these simple ratios was that a firm might rank high in efficiency when measured in terms of product per unit of one designated input, while requiring unusually large amounts of some other input.

Microeconomic Production Theory

According to C. E. Ferguson:

> The theory of production consists of an analysis of how businessmen--given the "state of the arts" or technology--combine various inputs to produce a stipulated output in an economically efficient manner.[1]

Producing an output in an economically efficient manner implied that, given the state of the arts or level of technology at a point in time, the maximum attainable output was produced from the given combination of inputs used.

---

[1] C. E. Ferguson, Microeconomic Theory (Revised Edition, Homewood, Illinois: Richard D. Irwin, Inc., 1969), p. 111.

Implicit in any productive process is a production function that relates the amounts of output from that process to the quantity of inputs used. This relation can be expressed as $Y = f(X_1, X_2)$, where output is Y and X_1 and X_2 are the two inputs, and can be expanded to include any number of inputs in n dimensional space.

In a continuous situation, a two-factor production function can be illustrated by an isoquant map. All factor combinations lying on an isoquant will yield the output level denoted by that curve.

An isoquant was defined by Ferguson as " . . . a curve in input space showing all possible combinations of inputs physically capable of producing a given level of output . . . ."[2] Assuming that operation is in the relevant range of production, increases in the use of both inputs will result in an increased output, as shown in Figure 3.1. The further an isoquant lies from the origin, the greater is the level of output represented. For example, in Figure 3.1, the curve labeled q(1) may define an output level of one unit while q(2) and q(3) define two and three units of output, respectively.

It is possible to produce the output denoted by q(1), in Figure 3.1, with any number of combinations of X_1 and X_2. At point M, one unit of X_1 and two units of X_2 are required to produce one unit of output. One unit of output can be produced also at point H, using two units of X_1 and one unit of X_2. Two units of output can be produced using two units of X_1 and four units of X_2; or any combination of factors indicated by points on curve q(2). The isoquant map in Figure 3.1 represents a

---

[2] Ibid., pp. 151-152.

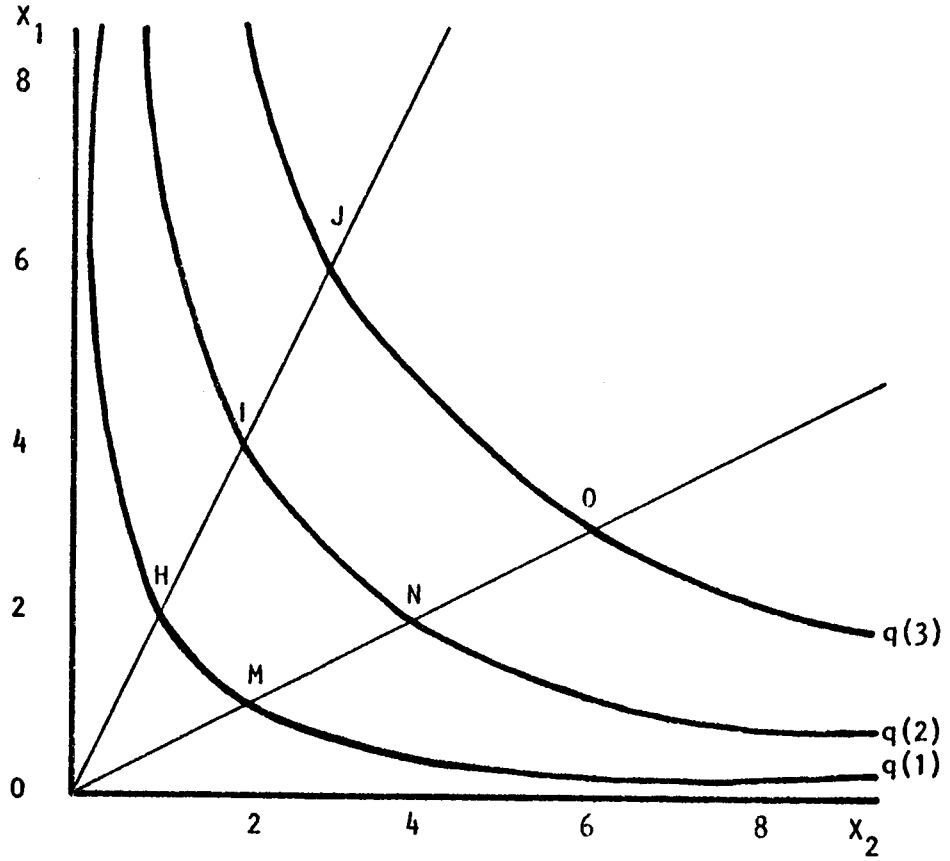


Figure 3.1. Hypothetical Isoquant Map: The Case of a Linear Homogenous Production Function.

linear homogenous production function.[3] Such a production function can be further summarized in a unit isoquant as shown in Figure 3.2. Efficient production occurs at different levels of output with factor combinations that are some multiple of the combination used by the unit isoquant.

The slope of an isoquant measured at a point of tangency, yields the marginal rate of technical substitution (MRTS). If the same level of output is to be maintained as the amount of one input is decreased, increasing amounts of a second input must be applied. The MRTS of input X_1 for X_2 at a point on an isoquant is equal to the negative of the slope of the isoquant at that point. Such an inverse relationship between rates of input substitution results in a curve that is downward sloping to the right.

Production functions are normally assumed to possess convex isoquants. Because the marginal rate of technical substitution of one factor for another equals the negative inverse ratio of the slope of the isoquant, the absolute value of the slope of the isoquant must be declining with movement to the right along a given isoquant. It follows, of course, that if the absolute value of the slope is getting smaller with movement to the right, the isoquant must be convex to the origin.

Just as production functions are characterized by isoquants, the total outlay surfaces can be described using isocost lines if factor prices are known. Graphically, this is done by adding isocost lines (such as QQ' or RR' in Figure 3.3), to the isoquant map. Such lines

---

[3] A linear homogenous production function implies constant returns to scale. An incremental percentage increase in the quantity of each input used, results in the same percentage increase in the level of output.

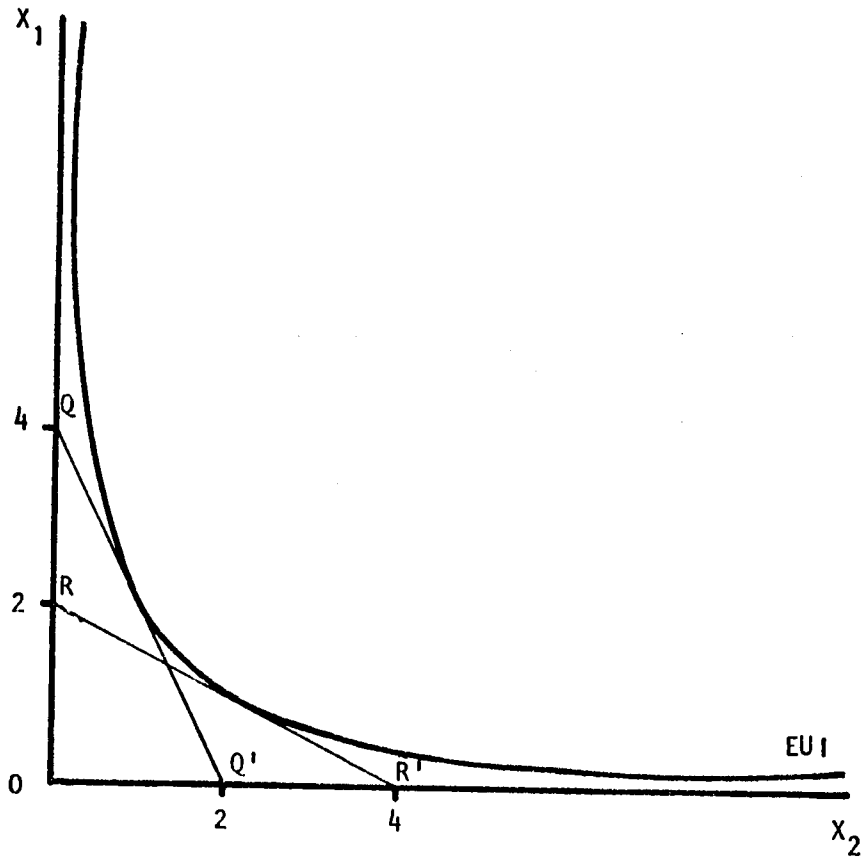


Figure 3.2. Hypothetical Unit Isoquant: The Case of a Linear Homogenous Production Function.

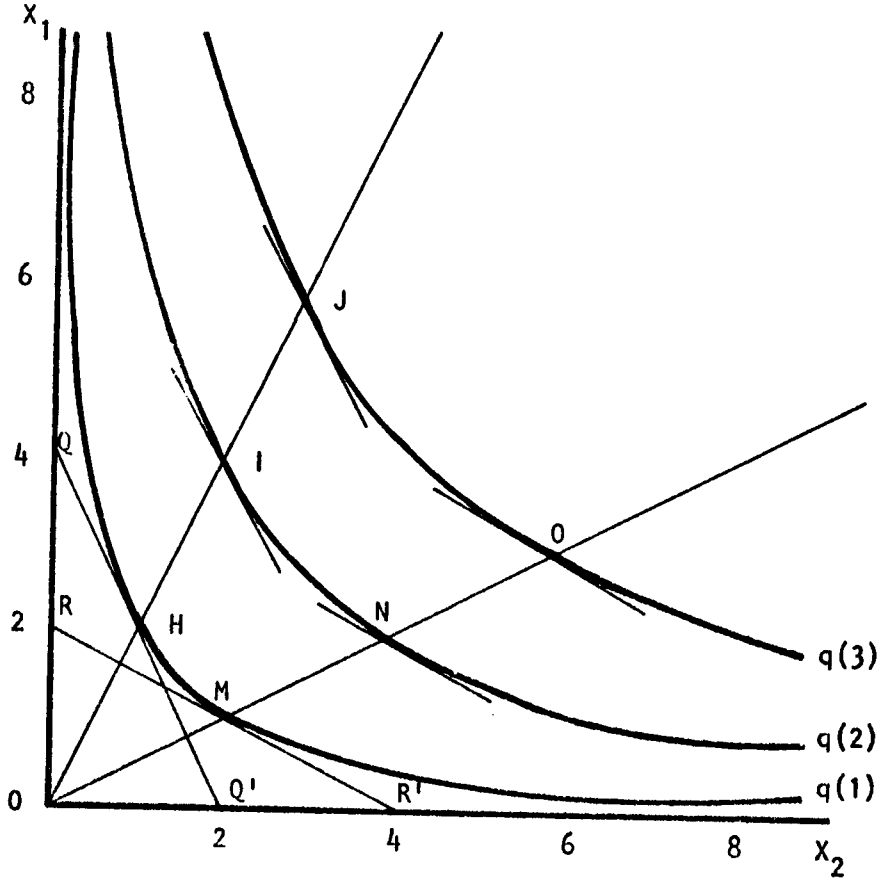


Figure 3.3. Hypothetical Isoquant Map with Relevant Isocost Lines Superimposed.

determine all combinations of two inputs that can be purchased by a firm at a given total outlay. The slope of the isocost line is given by the negative inverse ratio of the factor prices.

If the relevant isocost lines are superimposed on the firm's isoquant map, it is possible to determine which combination of inputs will maximize output (or minimize cost) for a given total outlay. The least cost combination of inputs is identified at the point of tangency between an isoquant and a specified isocost line. In Figure 3.3, with prices QQ' assumed to be the cost minimizing factor combination, production will occur at points H, I, and J for one, two, and three units of output, respectively. Similarly, assuming factor price combination RR' is cost-minimizing, points M, N, and O will identify output levels of one, two, and three units. Lines connecting cost minimizing factor combinations are called expansion paths. Such lines give factor proportions necessary for efficient production at various levels.

In any discussion of production functions, an important characteristic often noted is how output responds in the long-run to changes in scale of plant. In other words, suppose a long-run situation exists in which all inputs are variable and the firm increased the amount of inputs by the same proportion. The relevant question is--what will happen to output?

Three distinct conditions may exist. First, output may increase by a larger proportion than each of the inputs. For example, a doubling of all inputs may lead to more than a doubling of output. This is the case of increasing returns to scale. A second condition exists when a doubling of all inputs results in less than a doubling of output. This

is the case of decreasing returns to scale. Third, output may increase in exactly the same proportion as the increase in inputs. This is the case of constant returns to scale. A function of this nature is referred to as a linear homogenous production function.

Farrell Efficiency Measures

At this point, the efficiency model developed by Farrell[4] can be introduced. Initially, a linear homogenous production function was assumed. For simplicity, a two-input, single-output case also was assumed. With these two assumptions, the measures of efficiency proposed are shown in Figure 3.4. In this figure, point F represents a firm's actual use of the two factors of production per unit of output. The isoquant SS' shows the various combinations of factors for efficient production of one unit of output. Point G represents a firm producing one unit of output using the two factors in the same proportion as firm F. Firm G is producing at a fraction of the cost of firm F, as indicated by the distance from the origin. More specifically, Farrell proposed that the fractional cost, OG/OF x 100 would define the relative technical efficiency of firm F. Assuming that the isoquant SS' represented the most efficient use of the factors observed (or attainable), it takes the value of unity or 100 percent.

In addition to technical efficiency, Farrell also set forth a measure of the extent to which a firm utilized the factors of production in the best proportion, relative to their prices. In Figure 3.4, line

---

[4]Farrell, op. cit.

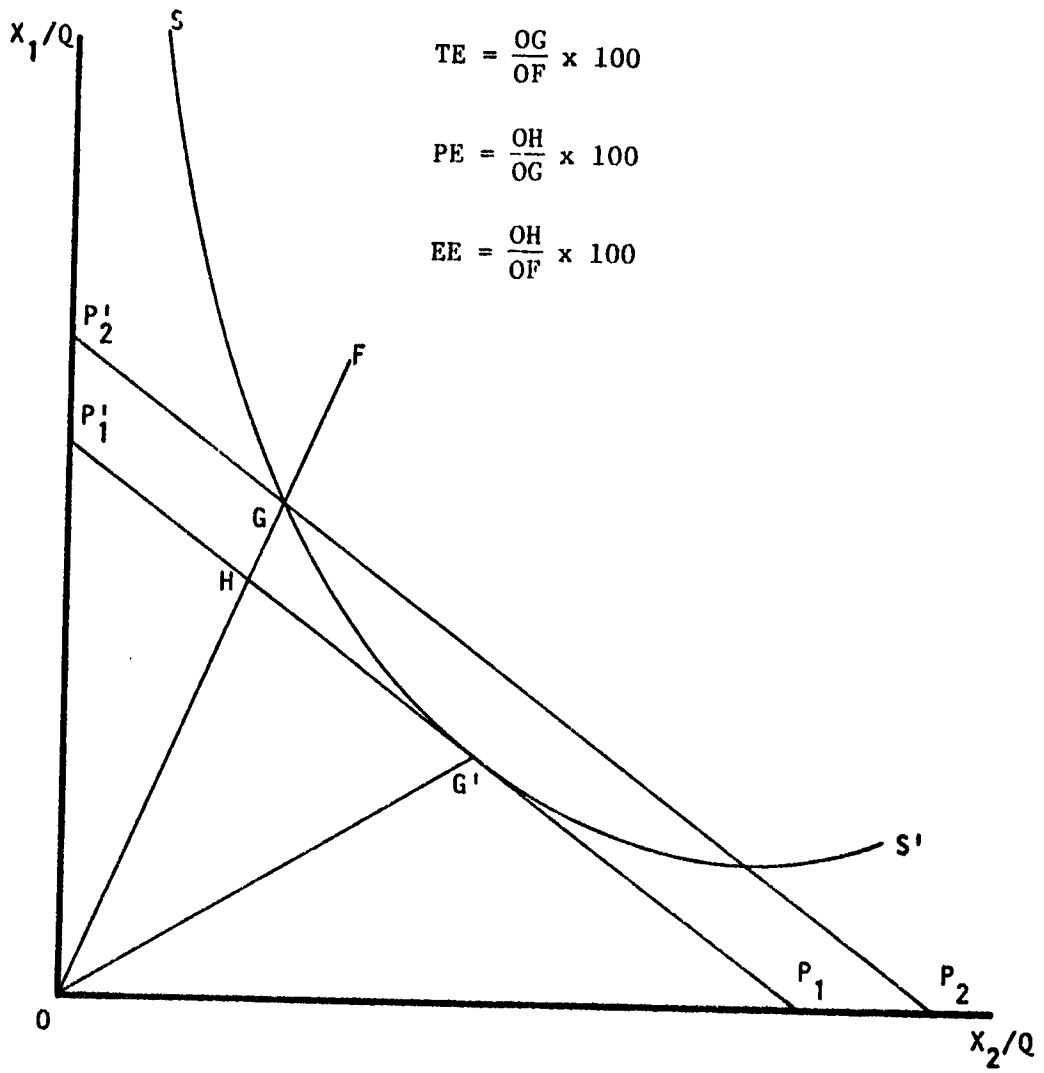


Figure 3.4. Illustration of Technical, Price, and Economic Efficiency.

P_1P_1' has a slope equal to the ratio of the prices of the two factors.[5] A point of tangency between the isoquant and the specified isocost curve P_1P_1', will identify a least cost combination of factors for optimal production. This point of tangency was defined by Farrell as 100 percent price efficient. However, if production occurred with a factor combination such as observed with firm F, price inefficiency existed. In this case, Farrell measured the extent of price inefficiency by the ratio OF/OG x 100. Production at point G also was inefficient since that activity was not using the optimum proportion of the factors of production. Production with this factor mix would involve the expenditure line P_2P_2', which is a higher total outlay requirement than at point G'.

If the observed firm F, had utilized both factors in the same ratio as a firm at G', firm F could be described as perfectly efficient. Farrell termed this index, economic or overall efficiency and defined it as the product of technical and price efficiency as measured by the ratio OH/OF x 100 as in Figure 3.4.

Approximation of the Unit Isoquant

Farrell defined the three measures of efficiency relative to an efficient unit isoquant (EUI). In this manner, observed performance of a firm could be compared with an assumed standard of perfect efficiency.

He indicated that two possibilities existed for approximating the efficient unit isoquant. The first was a "theoretical" frontier obtained by economic engineering methods. A standard of this order

---

[5]Factor prices for observed firms can be determined on the basis of industry or average prices; or prices can be established as prices paid by that firm under consideration for the factors utilized in production.

would represent the highest level of output attainable with known technology. However, Farrell argued against this approach, citing difficulties in estimating an efficient function for complex processes and the possibilities for human error. The second method obtained a frontier function based on the best performances of observed firms in the industry. This was the approach used to estimate the efficient unit isoquants in this study.

Using the best results observed in practice, Farrell estimated the efficient unit isoquant from observations of the inputs and outputs of a number of firms. Each firm, with inputs expressed on a per unit of output basis, was represented by a point on an isoquant map. A plot of all observations yielded a scatter of points as in Figure 3.5. The theoretical efficient unit isoquant was approximated by fitting an envelope from below to the set of observations. With the extensions to infinity on the horizontal and vertical axes, these points gave an estimate of the efficient unit isoquant. For example, in Figure 3.5, the curve SS' was termed a "conservative" estimate of the theoretical efficient unit isoquant.

All points not lying on the hypothetical efficient unit isoquant must be less than 100 percent technically efficient. Technical efficiency measures for such observations were arrived at by rating these points on the basis of linear combinations of points lying on the unit isoquant. This point was illustrated by Bressler[6] in a graphic display similar to Figure 3.6. Point e was rated as a weighted average of

---

[6]Bressler, op. cit., p. 132.

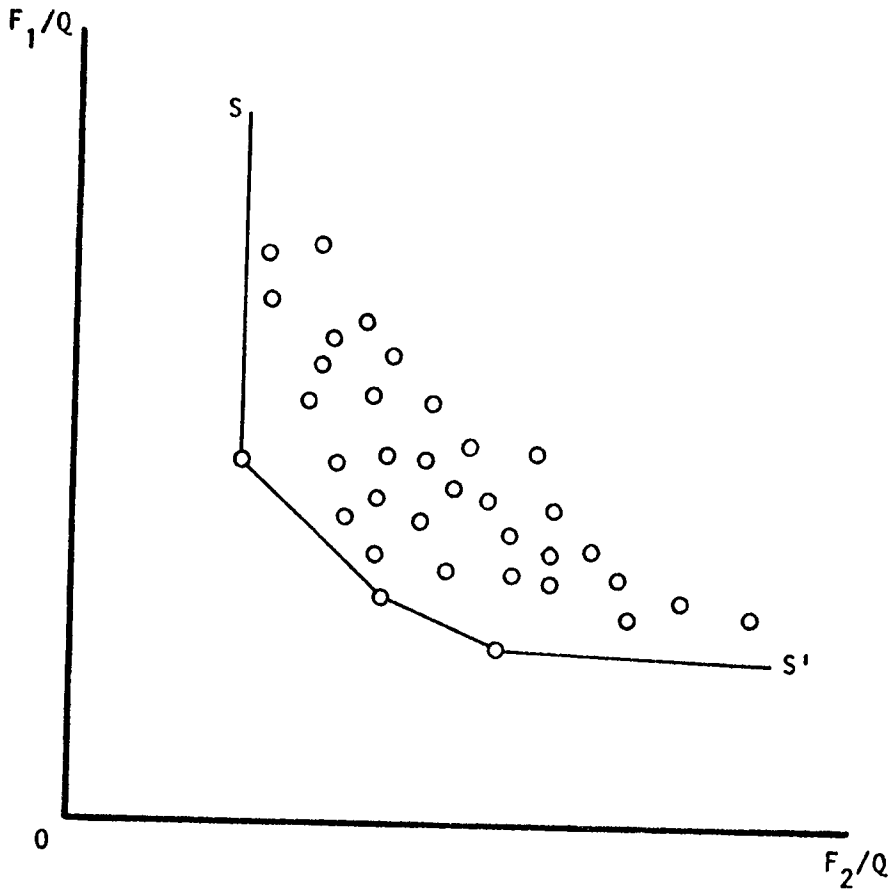


Figure 3.5. Hypothetical Efficient Unit Isoquant Approximated by Fitting an Envelope from Below to the Scatter of Observations.

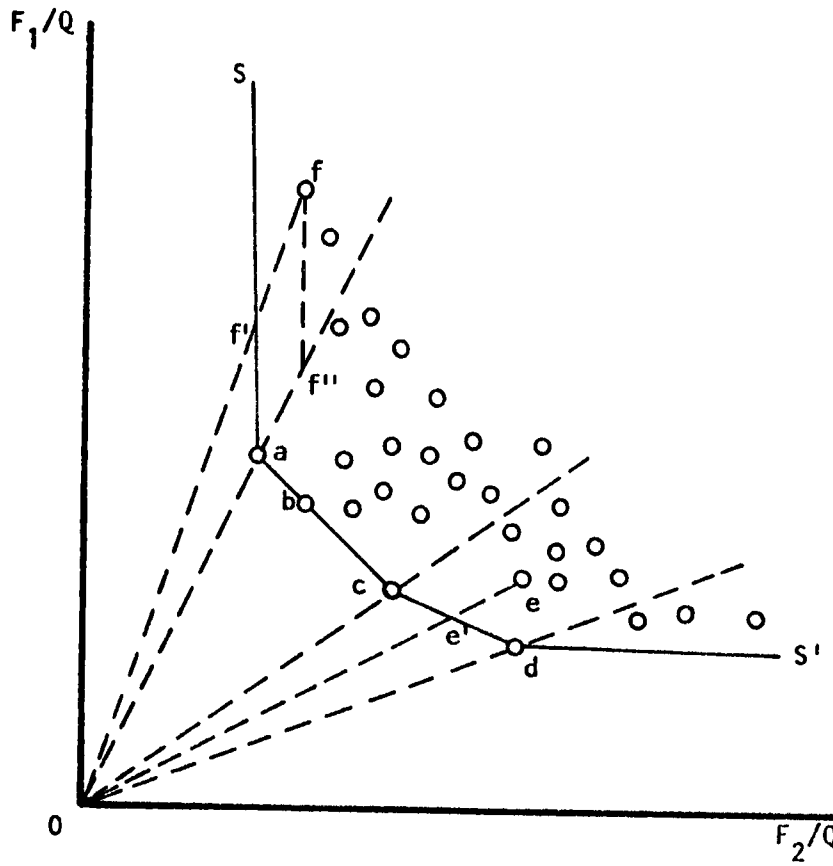


Figure 3.6. Hypothetical Example of the "Pessimistic" Estimate of the Efficient Unit Isoquant--Two Factor Case.

points a and d on the efficient unit isoquant. Likewise, all points within cone oabcd were rated with reference to a weighting of a and d, to yield unambiguous measures of technical efficiency. However, when observations fell outside the cone oabcd but within the envelope SS', the measures of technical efficiency became less precise. Point f is a good example of this phenomenon. Technical efficiency was measured as the ratio of'/of for this observation. This ratio was equivalent to the ratio oa/of" when rated relative to points on the envelope of cone oabcd since the efficient unit isoquant defined factor combinations yielding the same level of output. Technical efficiency ratings for points such as f indicated that all inputs could be reduced by some ratio, yet, disposal of an additional quantity of F_1 would be necessary for efficient operation. For example, a technical efficiency rating of 0.80 indicated that all inputs could be reduced in the ratio of 100 to 80, yet, disposal of F_1 in the amount of ff" would be necessary to produce on the efficient unit isoquant.

CHAPTER IV

DATA AND METHODOLOGY

I. THE THEORETICAL MODEL

The model developed by Boles[1] was used to estimate technical efficiency for the firms in the study. The objective was to classify each of the n points as 100 percent efficient (forming a hyperplane of the efficient unit isoquant), or if less than 100 percent efficient, to compute a relative technical efficiency index.

The basic unit of observation was a productive activity with a bundle of inputs standardized to yield one unit of output. By definition, the j_{th} activity would produce one unit of output. Therefore, the efficiency rating of an activity P_j could be established with a linear programming model as follows:

1. Maximize $X_o = V'X$

   subject to $X \geq 0$

2. $AX \leq P_j$

   where,

   X_o = optimum value of the objective function

   V = n + 1 vector of ones

   X = list of inputs standardized to produce one unit of output

---

[1] James N. Boles, "Efficiency Squared--Efficient Computation of Efficiency Indexes," Western Farm Economics Association, 1966 Proceedings (Pullman, Washington, 1967), pp. 137-142.

A = a matrix, the columns of which are the $\underline{n}$ activities

P_j = one of the $\underline{n}$ standardized activities each producing one unit of output

$V'X$ = maximum total output attainable from a list of inputs used by j_{th} activity to produce one unit of output.

The computation began with an activity that used the minimum amount of one of the $\underline{m}$ factors, say the first. At this point, the activity was classified efficient. This activity became the first right-hand-side (rhs) and the algorithm determined an optimal solution.

At this point, the remaining activities were unclassified. One of these activities was selected to become the new rhs. As this new rhs entered the algorithm, the linear programming problem was: What was the maximum amount of output that could be produced with this new list of inputs? If this combination of inputs could produce more than one unit of output while using no more than the requirements of the j_{th} activity, the previous activity was inefficient. This process was repeated until each activity was classified with respect to the total list of $\underline{m}$ factors included in the analysis.

Technical efficiency for the activity P_j was equivalent to $\frac{1}{X_o} \times 100$, where X_o was the maximum value of the objective function. Following solution of the $\underline{n}$ activities, the efficient unit isoquant (EUI) was defined in terms of activities for which technical efficiency was equal to one (TE = 1). All remaining activities were given relative technical efficiency ratings.

Price efficiencies for the activities in the sample were calculated in much the same manner as technical efficiency. Expenditures

for factors of production were expressed on a per unit of output basis to form input-output ratios for the n activities. Activities for which price efficiency was equal to one (PE = 1), were assumed to represent the minimum cost of production. All other activities were assigned relative price efficiency indexes, based on their observed costs of production.

Economic efficiency measures were calculated for the n activities as the product of their respective technical and price efficiency measures.

II. SELECTION OF VARIABLES

The five inputs used in the Farrell analysis were hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials. These five items were assumed to be key factors in estimating efficiencies of the firms in the sample.

Total expenditures in 1974 and 1975 for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials were obtained by personal interviews with owners and/or managers of each firm in the sample. Gross sales for both 1974 and 1975 also were obtained during the interview. This variable was selected as a measure of output. The dressed weight of output was not used to measure final output because of variations in the services provided by custom slaughterers and commercial slaughterers. Also, tonnage output figures were often unavailable and had to be estimated, whereas, gross sales was a bookkeeping item in all of the plants in the survey.

Calculation of Physical Amounts of Inputs

Physical amounts of the five selected inputs were needed to estimate technical efficiency for the 40 firms in the sample. Since only dollar expenditure records were kept by the firms in the sample, this necessitated calculation of quantities of hired labor, electricity, water and sewage service, and natural gas used from applicable rate schedules.

Total hours of hired labor for each firm was calculated by dividing annual wages paid by average hourly earnings of non-supervisory personnel in the Food and Kindred Products Industry for Tennessee.[2]

Kilowatt hours (Kwh) of electricity consumed by the firms in the sample were calculated from monthly rates reported by the United States Federal Power Commission.[3] This rate schedule reported typical residential, commercial, and industrial bills per 1000 Kwh by state and community. Total consumption of electricity for each firm was estimated by dividing the monthly charges reported by each observation by the rate per 1000 Kwh.

Amounts of natural gas used by each of the firms in the survey were estimated using cost rates published by the American Gas Association (A. G. A.).[4] Varying units of measure for different suppliers

---

[2]United States Department of Labor, Bureau of Labor Statistics, Employment and Earnings, States and Areas, 1939-1975 (Washington, D. C.: United States Government Printing Office, 1976).

[3]United States Federal Power Commission, Typical Electric Bills, 1973-1975 (Washington, D. C.: United States Government Printing Office, 1976).

[4]American Gas Association, A. G. A. Rate Service (New York: American Gas Association, Inc., 1975).

were converted to therms[5] to obtain a standard of measure throughout Tennessee. Again, as with electricity, physical amounts consumed were found by dividing monthly charges by the cost per unit.

Consumption of water and sewage service was measured on a 1000 gallon basis. Rate schedules used were taken from data published by the Tennessee State Planning Office.[6] Quantities consumed and discharged by each plant were obtained by summing the charge for water and sewage service per 1000 gallons and dividing the monthly charges by the rate per unit.

Physical amounts of supplies and cleaning materials were estimated by assuming that a dollar expenditure for this input variable corresponded to one unit.

III. METHODS OF ANALYSIS

Technical, price and economic efficiencies were estimated for all firms in the sample. Two algorithms were used. The first grouped all firms together. The second was used to determine if there were differences in efficiencies between the commercial slaughterers and the custom slaughterers in the sample.

The Composite Model

Estimated quantities of inputs and dollar expenditures on inputs were used to calculate technical, price, and economic efficiency for the composite sample of 40 firms in 1974 and 1975.

---

[5] $\text{Total therms} = \frac{\text{Cubic feet} \times \text{Btu/cubic feet}}{100{,}000}$

[6] Tennessee State Planning Office, Sanitary Services in Tennessee (Nashville, Tennessee, 1975).

Estimated amounts of hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials for both custom and commercial slaughterers were expressed on a per unit of output basis for calculating technical efficiency. A linear programming algorithm was used to estimate the efficient unit isoquant (EUI) and the technical efficiency for each firm in the sample, under 1974 conditions. The algorithm used a single pass of the MPS/360 package[7] to obtain a solution for the 40 firms in the sample. The algorithm was repeated, using 1975 data, to obtain an estimate of the EUI and technical efficiency measures for that year.

The relative technical efficiency for each firm was determined as $\frac{1}{X_o} \times 100$, where X_o was the value of the objective function. The iterative solution process gave a value for the objective function as each firm's inputs appeared as a right-hand-side of the linear programming problem. Multiplication by 100 expressed the objective function as a percent measure.

Dollar expenditures for each of the five input variables in the study were expressed on a per unit of output basis to determine price efficiencies for the firms in the sample. The input-output ratios for each firm appeared as a right-hand-side as the iterative solution was found for each firm.

Price efficiency was equal to $\frac{1}{X_o} \times 100$. Observations assigned a price efficiency rating of 100 percent represented the firms that were

---

[7]The MPS/360 package is a canned statistical program available at the University of Tennessee Computing Center and is capable of solving a variety of linear programming problems. A list of the control cards used in the algorithm for this study is contained in Appendix D.

perfectly efficient with regard to adjustments to factor prices for the five variables included in the analysis. Firms with higher total expenditures per unit of output were assigned relative price efficiency measures. Again, the model was run a second time, using 1975 data, to obtain price efficiency measures for that year.

Economic efficiency ratings for each of the 40 observations were formed as the product of their respective technical and price efficiency ratings. Firms that were 100 percent economically efficient had minimum average costs of production. All other firms were assigned relative price efficiency ratings to reflect higher average costs of production.

Split Sample Analysis

A second analysis was made in which firms in the sample were classified as either custom slaughterers or commercial slaughterers, based on the type of license held by that firm. Seventeen of the forty firms held custom slaughtering licenses, and the remaining twenty-three were commercial slaughterers.

Technical, price, and economic efficiency measures were obtained for 1974 and 1975 in the same manner as in the composite sample analysis.

Test for Significance

In the composite analysis, the Mann-Whitney rank-sum test[8] was used to test the null hypothesis that the mean economic efficiency measure for the 40 observations remained unchanged between 1974 and 1975. In this manner, it could be determined if the minimum average cost of production

---

[8]John E. Freund, Modern Elementary Statistics (Third Edition, Englewood Cliffs: Prentice-Hall, Inc., 1967), pp. 320-322.

changed a significant amount during the period of the study. If the mean economic efficiency measure changed significantly between 1974 and 1975, it could be assumed that the minimum average cost of production changed significantly because of the inverse relationship between measures of economic efficiency and the average costs of production.

The Mann-Whitney rank-sum test also was used to test for a significant change in the mean economic efficiency ratings for the two subsamples in the split analysis. In this case, the test was used to determine if a change occurred in economic efficiency for the two groups of slaughterers when analyzed individually. A short explanation of the Mann-Whitney test is contained in Appendix A.

The Kruskal-Wallis rank-sum test[9] was used to test the null hypothesis that the 40 independent observations came from the same population against the alternative hypothesis that the mean of the custom slaughterer efficiency measures was not equal to the mean of the commercial slaughterer efficiency measures.

The rank-sum values used in the Kruskal-Wallis test were economic efficiency ratings for the respective observations in the split analysis. A short explanation of the Kruskal-Wallis test is contained in Appendix B.

---

[9] Ibid., pp. 323-324.

CHAPTER V

RESULTS AND DISCUSSION

One of the specific objectives of this study was to determine the changes that have occurred in expenditures for energy sources, petrochemical based materials, and related items used in the Tennessee meat packing and processing industry between 1974 and 1975. The impact of increased costs for inputs to production in this industry is assumed to be reflected in expenditures reported by each firm for the two-year period under study.

In turn, relative technical, price, and economic efficiencies were expected to reflect increased costs for inputs to production. An analysis of the three measures of efficiency for the 40 firms in the study fulfilled Objective 2 of the study.

Objective 3 was accomplished by estimating the economic efficiency indexes for each firm for 1974 and 1975. The average cost of production for each firm was assumed equivalent to the inverse ratio of economic efficiency for that firm.

I. CHANGES IN EXPENDITURES FOR INPUTS

Total expenditures for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials reported for 1974 and 1975 are given in Tables C.1 and C.2.

Expenditures per $1,000 of gross sales for 1974 and 1975, for the five inputs, are given in Table 5.1.

Table 5.1 Expenditures for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials per $1000 gross sales, 1974 and 1975.[a]

Observation	Hired Labor		Electricity		Water and Sewage Service		Natural Gas		Supplies and Cleaning Materials	
	1974	1975	1974	1975	1974	1975	1974	1975	1974	1975
001	164.46	151.24	14.36	18.75	4.65	4.30	11.55	10.94	81.18	93.49
002	76.99	90.18	5.16	6.87	.69	.65	3.45	4.43	47.76	47.15
003	121.15	110.96	16.15	19.50	4.35	3.25	7.04	7.13	91.66	93.04
004	222.09	254.04	66.85	75.50	7.93	13.47	11.21	18.54	98.07	132.00
005	106.66	112.02	61.50	71.39	3.71	5.15	7.78	10.84	156.16	152.79
006	94.56	125.65	30.22	45.32	1.06	1.17	3.62	3.82	95.05	121.69
007	44.63	49.29	3.08	4.36	.32	.32	1.46	1.99	52.81	57.49
008	202.38	164.98	14.29	8.75	.55	.45	3.65	3.15	83.04	61.00
009	198.39	238.07	19.83	29.12	1.44	1.72	2.76	3.99	84.99	123.48
010	44.65	70.69	14.99	22.63	3.12	2.89	9.37	11.56	86.41	87.45
011	244.09	257.96	31.26	27.32	4.27	3.31	7.09	7.55	108.19	101.10
012	84.64	94.77	12.91	14.70	1.32	1.52	4.73	3.28	76.57	67.22
013	76.60	94.79	3.28	4.20	.45	.64	.30	1.16	50.80	64.79
014	144.44	136.13	19.07	34.55	4.67	2.20	13.22	7.20	88.89	73.30
015	172.02	257.94	21.08	22.13	3.72	4.14	11.25	13.82	56.25	73.32
016	113.45	132.30	24.50	27.95	1.63	2.05	21.00	23.84	61.25	69.86
017	190.57	171.33	22.22	30.59	1.87	1.57	6.30	4.07	110.66	122.38
018	240.00	200.00	50.54	46.80	4.80	2.00	16.00	10.67	70.00	66.67
019	188.53	219.31	3.71	4.52	1.16	1.34	1.31	1.90	51.12	58.32
020	109.19	126.27	7.19	9.32	1.08	.94	5.39	4.37	59.86	63.65
021	114.27	128.60	15.81	21.18	1.99	2.16	5.31	7.71	51.66	83.54
022	191.81	215.84	6.64	7.67	1.77	1.51	4.69	4.94	68.25	74.89
023	116.38	108.61	8.12	6.93	.53	.44	2.39	2.33	67.66	75.99
024	129.19	141.40	19.25	27.33	1.86	2.10	7.49	9.48	69.71	95.48
025	57.27	57.47	5.79	6.94	.58	.48	2.86	2.64	46.50	53.60
026	186.67	208.00	16.67	28.80	.79	1.07	10.00	12.00	100.00	136.00
027	105.29	117.61	80.88	71.80	5.16	7.50	6.07	6.90	108.74	163.66
028	71.42	84.76	11.98	12.66	1.26	.86	9.47	9.85	68.07	103.24
029	110.94	133.17	12.17	15.96	3.03	2.61	7.98	9.50	85.98	79.78
030	182.20	132.87	59.71	52.36	4.20	2.92	22.70	15.23	158.00	113.28
031	84.16	78.05	9.22	10.09	1.29	1.12	3.22	3.10	94.59	117.58
032	116.76	120.45	16.49	17.84	3.05	2.63	9.30	9.39	55.64	68.65
033	183.76	189.52	16.93	19.26	3.46	3.59	6.77	7.76	55.86	86.84
034	128.02	166.36	25.98	39.97	2.04	2.64	28.62	28.27	191.51	217.76
035	111.21	140.31	12.41	17.67	1.48	1.89	8.47	7.87	160.84	188.51
036	141.85	195.11	15.93	28.17	1.09	1.34	7.59	11.61	79.81	116.36
037	240.75	298.56	35.15	46.63	3.81	4.74	13.85	20.56	193.86	216.26
038	119.54	124.08	19.03	17.47	1.39	1.26	6.34	6.44	63.22	64.01
039	223.69	233.22	26.27	40.27	2.26	2.64	6.27	6.56	81.11	64.61
040	123.69	122.82	46.03	43.04	9.20	7.18	14.39	16.25	150.85	172.24

[a]Source: Survey of Tennessee Meat Packing and Processing Industry, April-May, 1976.

Hired Labor

Thirty firms experienced increased expenditures for hired labor between 1974 and 1975. There was considerable variation among the firms in the sample in their expenditures for this input. Some of the variation can be explained by the fact that several owners and their families often worked but accepted no direct wages. Any profit remaining at the end of the tax period was taken in lieu of a salary.

Electricity

Thirty-two firms paid more for electricity in 1975 than in 1974. Variations in expenditures among firms reflected abilities of some firms to take energy-saving steps such as turning off coolers during slack slaughtering periods, and slaughtering only two or three days per week.

Water and Sewage Service

Fewer firms indicated increased expenditures for water and sewage service than any other input included in the analysis. Only 19 of the 40 firms paid more for this utility in 1975, compared to 1974. Respondents interviewed during the survey indicated that this input was the most visible and easiest one for applying conservation measures.

Natural Gas

Twenty-seven firms paid more for natural gas in 1975 than in 1974. Variations in expenditures among firms can be explained in part from the use by some plants of natural gas for heating buildings. Also, some plants skinned hogs rather than scalding them. This conserved

both water and natural gas. Some plants reported that hogs were killed on one specific day each week, thus eliminating the need to heat a vat of water every day. Other plants no longer scaled hogs but skinned them instead, although the value of hides often made it unprofitable to process them.

Supplies and Cleaning Materials

Thirty firms reported that they paid more for supplies and cleaning materials in 1975 than in 1974. This input increased in cost about 15 percent during the period of the study. Several firms indicated that they avoided some of the cost increases by early stockpiling of boxes, tape, and freezer paper. Other firms established strict conservation measures to reduce waste and, in turn, reduce the cost of supplies and cleaning materials.

II. ANALYSIS OF EFFICIENCY INDEXES

The efficient unit isoquant obtained from the five-factor single-output analysis, estimated the frontier production function for the 40 observations in the sample. This approximation identified the minimum input-output ratios with alternative factor combinations necessary to produce one unit of output. All activities lying on the efficient unit isoquant were assigned a technical efficiency rating equal to one (TE = 1). Those activities identified the "best" observed performance of the plants sampled in their utilization of the factors included in the analysis.

All activities not lying on the frontier production function were assigned technical efficiency measures relative to the postulated

standard set forth by the EUI. The relative measures represented the proportions to which all factors could be reduced if production was carried on with identical factor proportions, but at the efficient level. For example, a firm rated 90 percent technically efficient could reduce all inputs in the ratio of 100 to 90, while maintaining the same level of output.

The positioning of the EUI and the slope of the factor prices line determined the price efficiency measures for the firms in the sample. Firms utilizing a factor mix that minimized total outlay (was just tangent to the minimum factor prices line) for one unit of output, was rated efficient. Factor combinations that were not tangent to the minimum factor prices line required a higher total outlay and were assigned lower relative price efficiency measures.

Firms that were efficient, both technically and with respect to their adjustments to factor prices, were assigned 100 percent economic efficiency ratings. This measure was formed as the product of technical and price efficiency coefficients.

As indicated, two approaches were used in the analysis of efficiency indexes. The first, a composite model of both custom and commercial slaughterers, assumed that no differences existed in the scale and production characteristics of the two groups of firms. The second approach divided the slaughterers into two samples, based on the type of license held by the firm. Efficiency measures were found for the individual observations in each group.

III. THE COMPOSITE ANALYSIS, 1974 AND 1975

Technical Efficiency Indexes, 1974 and 1975

The technical efficiency indexes for the 40 observations, consisting of commercial and custom slaughterers, are shown in Tables 5.2 and 5.3. Output levels measured in gross sales of product are also given.

The analysis for 1974 rated four firms 100 percent technically efficient. All four held commercial slaughter licenses. Average technical efficiency for the sample of 40 firms was about 65 percent for 1974 (Table 5.4).

The algorithm was repeated with 1975 data. Six firms were rated 100 percent technically efficient. As in 1974, the firms most efficient in factor utilization were commercial slaughterers.

Observations that were unclassified at this time were assigned relative technical efficiency measures on the basis of their position relative to the efficient unit isoquant. Average technical efficiency for all firms in the sample in 1975 was about 63 percent (Table 5.4).

Price Efficiency Indexes, 1974 and 1975

Price efficiency indexes for 1974 and 1975 are shown in Tables 5.2 and 5.3 above. These measures were found with the linear programming algorithm using "own"[1] factor prices data, as the model was

---

[1]Factor prices faced by the individual firm were used in determining price efficiency for this study. These prices were referred to as "own" prices as opposed to assuming constant and equal prices for all of the observations in the sample.

Table 5.2. Technical efficiency (TE), price efficiency (PE), economic efficiency (EE), and level of output[a] for 1974

Observation	Output ($)	TE (%)	PE (%)	EE (%)
001	52,661	57.27	57.28	32.80
002	617,000	97.47	99.68	97.16
003	48,286	51.09	50.73	25.92
004	39,094	47.40	47.42	22.48
005	52,812	41.77	41.78	17.45
006	141,818	54.28	53.11	28.83
007	248,103	100.00	100.00	100.00
008	336,000	69.12	62.85	43.44
009	219,670	58.97	57.24	33.75
010	48,028	100.00	100.00	100.00
011	63,500	43.89	42.98	18.86
012	443,000	63.20	63.19	39.94
013	1,359,595	100.00	100.00	100.00
014	109,300	52.30	52.31	27.36
015	199,133	82.65	82.67	68.33
016	400,000	75.90	75.92	57.62
017	244,000	44.52	42.32	18.84
018	50,000	66.41	66.43	44.12
019	1,349,288	99.04	98.16	97.22
020	1,415,594	77.66	78.17	60.71
021	84,212	89.99	90.01	81.00
022	354,510	71.14	70.86	50.41
023	386,655	88.86	75.29	66.90
024	92,110	66.69	66.70	44.48
025	406,000	100.00	100.00	100.00
026	150,000	54.65	50.83	27.78
027	28,684	46.55	46.55	21.67
028	128,977	72.40	72.39	52.41
029	286,818	54.07	54.08	29.24
030	28,101	30.16	30.16	9.10
031	93,280	58.17	54.97	31.98
032	198,000	83.55	83.57	69.82
033	184,200	83.23	83.24	69.28
034	96,078	34.83	34.83	12.13
035	108,159	40.14	40.11	16.10
036	108,000	58.25	58.26	33.94
037	31,776	23.98	23.99	5.75
038	82,330	73.54	73.55	54.09
039	204,000	57.52	57.33	32.98
040	37,190	36.08	36.07	13.01

[a]Source: Survey of Tennessee Meatpacking and Processing Industry conducted as a part of this study, April-May, 1976.

Table 5.3 Technical efficiency (TE), price efficiency (PE), economic efficiency (EE), and level of output[a] for 1975

Observation	Output ($)	TE (%)	PE (%)	EE (%)
001	58,402	52.66	52.66	27.73
002	596,000	100.00	100.00	100.00
003	57,185	56.48	56.48	31.90
004	35,499	35.70	35.72	12.75
005	46,965	43.99	44.00	19.36
006	128,114	51.65	48.29	24.94
007	1,251,028	100.00	100.00	100.00
008	594,000	92.78	89.90	83.41
009	154,890	47.99	47.27	22.68
010	51,916	69.74	69.73	48.63
011	83,811	50.71	49.19	24.94
012	420,818	76.16	79.91	60.86
013	1,112,412	100.00	100.00	100.00
014	191,000	64.84	64.84	42.04
015	183,762	63.78	64.31	41.02
016	365,000	67.48	67.67	45.66
017	286,000	46.68	47.41	22.13
018	75,000	60.19	100.00	60.19
019	1,257,400	100.00	99.95	99.95
020	1,561,211	74.08	79.48	58.88
021	79,922	59.84	59.63	35.68
022	406,560	73.50	70.86	52.08
023	506,416	100.00	81.24	81.24
024	88,400	52.64	52.64	27.71
025	450,000	100.00	100.00	100.00
026	125,000	41.50	39.83	16.53
027	20,542	41.91	41.91	17.56
028	143,816	58.16	58.15	33.82
029	352,212	61.23	61.23	37.49
030	45,835	46.56	46.55	21.67
031	113,000	76.00	63.87	48.54
032	224,500	70.27	70.27	49.38
033	191,480	58.68	54.98	32.26
034	79,554	29.62	29.63	8.78
035	104,073	35.14	35.13	12.34
036	76,315	41.94	42.64	17.88
037	27,236	23.60	23.60	5.57
038	74,590	74.82	73.66	55.11
039	235,600	74.64	72.98	54.47
040	42,337	40.15	40.13	16.11

[a]Source: Survey of Tennessee Meatpacking and Processing Industry conducted as a part of this study, April-May, 1976.

Table 5.4 Frequencies and average efficiency of measures of technical efficiency (TE), price efficiency (PE), and economic efficiency (EE), gross sales used as a measure of output, 1974 and 1975

	Number of Observations					
	1974			1975		
%	TE	PE	EE	TE	PE	EE
100	4	4	4	6	5	4
90-99	2	3	2	1	1	1
80-89	5	3	1	0	2	2
70-79	5	6	0	7	6	0
60-69	4	4	5	6	6	2
50-59	10	10	4	8	6	3
Below 50	10	10	24	12	24	28
Average efficiency percentage	65.17	64.38	46.42	62.86	63.29	43.78

repeated to obtain price efficiency measures for the entire sample in 1974 and 1975.

The same four firms identified as 100 percent technically efficient were also 100 percent efficient in their adjustments to factor prices in 1974. Average price efficiency for all firms in the sample in 1974 was about 64 percent (Table 5.4).

Price efficiency measures were found for each observation in 1975 by substituting factor price data for that year in the linear programming algorithm. Five firms were 100 percent efficient in adjustments to factor prices. Three of these five firms also were 100 percent technically efficient in 1975. Four of the price efficient firms held commercial slaughtering licenses, while one was a custom slaughterer. Average price efficiency for the firms in the sample in 1975 was about 63 percent (Table 5.4).

Economic Efficiency Indexes, 1974 and 1975

Economic efficiency indexes were calculated as the products of the estimated technical and price efficiency measures that were obtained previously. These measures for 1974 and 1975 are given in Tables 5.2 and 5.3.

The same four firms that were 100 percent technically efficient and price efficient in 1974 were also 100 percent economically efficient. Economic efficiency indexes were calculated for the remaining 36 firms in the sample. The average economic efficiency in 1974 for the firms in the sample was about 46 percent (Table 5.4).

Four firms were 100 percent economically efficient in 1975. The average economic efficiency in 1975 for the firms in the sample was about 44 percent (Table 5.4).

The Mann-Whitney rank-sum test for a change in the average economic efficiency index between 1974 and 1975 showed no significant change between the two years. This suggests that no significant change occurred in the average costs of production between 1974 and 1975 (Table A.1).

IV. THE SPLIT ANALYSIS, 1974 AND 1975

In the "split" analysis, the custom and commercial slaughterers in the sample were separated into two groups, and efficiency indexes estimated for each firm within groups. Seventeen firms were custom slaughterers, and twenty-three held commercial slaughtering licenses. Technical, price, and economic efficiency indexes estimated for 1974 and 1975 are given in Tables 5.5 and 5.6.

Technical Efficiency Indexes, 1974 and 1975

In 1974, seven custom slaughterers and four commercial slaughterers were identified as 100 percent technically efficient when efficiency indexes for the two groups were calculated separately (Tables 5.5 and 5.6). Average technical efficiency for the custom slaughterers was about 88 percent (Table 5.7), and about 76 percent for the commercial slaughterers in the sample (Table 5.8).

Five custom and six commercial slaughterers had technical efficiency ratings of 100 percent in 1975. The six commercial slaughterers found to be 100 percent technically efficient were also 100 percent

Table 5.5 Technical efficiency (TE), price efficiency (PE), economic efficiency (EE), and level of output[a] for custom slaughterers, 1974 and 1975

Observation	1974				1975			
	Output ($)	TE (%)	PE (%)	EE (%)	Output ($)	TE (%)	PE (%)	EE (%)
001	52,661	90.70	87.62	79.47	58,402	88.68	86.77	76.95
003	48,286	100.00	98.24	98.24	57,185	100.00	100.00	100.00
004	39,094	67.26	64.46	43.36	35,499	53.04	48.78	25.87
005	52,812	100.00	100.00	100.00	46,965	99.06	99.05	98.12
011	63,500	75.64	71.62	54.17	83,811	76.36	71.65	54.71
014	109,300	81.71	82.14	67.12	191,000	90.39	90.40	81.71
017	244,000	100.00	85.81	85.81	286,000	100.00	100.00	100.00
018	50,000	90.31	90.31	81.56	75,000	98.91	100.00	98.91
022	354,510	100.00	100.00	100.00	406,560	100.00	100.00	100.00
024	92,110	100.00	93.74	93.74	88,400	87.12	85.28	74.30
029	286,818	100.00	100.00	100.00	352,212	100.00	100.00	100.00
030	28,101	62.84	62.00	38.96	45,835	88.71	87.03	77.20
034	96,078	90.11	91.36	82.32	79,554	70.84	72.04	51.03
036	108,000	97.61	100.00	97.61	76,315	73.56	79.52	58.49
037	31,776	53.66	48.84	26.21	27,236	41.40	40.14	16.62
038	82,230	100.00	100.00	100.00	74,590	100.00	100.00	100.00
040	37,190	87.63	87.71	76.86	42,337	90.41	90.34	81.68

[a]Source: Survey of Tennessee Meat Packing and Processing Industry conducted as a part of this study, April-May, 1976.

Table 5.6 Technical efficiency (TE), price efficiency (PE), economic efficiency (EE), and level of output[a] for commercial slaughterers, 1974 and 1975

Observation	1974 Output ($)	1974 TE (%)	1974 PE (%)	1974 EE (%)	1975 Output ($)	1975 TE (%)	1975 PE (%)	1975 EE (%)
002	617,000	97.47	99.68	97.16	596,000	100.00	100.00	100.00
006	141,818	54.28	53.11	28.83	128,114	51.65	48.29	29.94
007	248,103	100.00	100.00	100.00	1,251,028	100.00	100.00	100.00
008	336,000	69.12	62.85	43.44	594,000	92.78	89.90	83.41
009	219,670	58.97	57.24	33.75	154,890	47.99	47.29	22.69
010	48,028	100.00	100.00	100.00	51,916	69.74	69.73	48.63
012	443,000	63.20	63.19	39.94	420,818	76.16	79.91	60.86
013	1,359,595	100.00	100.00	100.00	1,112,412	100.00	100.00	100.00
015	199,133	82.65	82.67	68.33	183,762	64.31	64.31	41.36
016	400,000	75.90	75.92	57.62	365,000	67.49	67.67	45.67
019	1,349,288	99.04	98.16	87.22	1,257,400	100.00	99.95	99.95
020	1,415,595	77.66	78.17	60.71	1,561,211	74.08	79.48	58.88
021	84,212	89.99	90.01	81.00	79,922	59.84	59.63	35.68
023	386,655	88.86	75.29	66.90	506,416	100.00	81.24	81.24
025	406,000	100.00	100.00	100.00	450,000	100.00	100.00	100.00
026	150,000	54.65	50.83	27.78	125,000	41.50	39.83	16.53
027	28,684	46.55	46.55	21.67	20,542	41.91	41.91	17.56
028	128,977	72.40	72.39	52.41	143,816	58.16	58.15	33.82
031	93,280	58.17	54.97	31.98	113,000	76.00	63.87	48.54
032	198,000	83.55	83.57	69.82	224,500	70.27	70.27	49.38
033	184,200	83.22	83.24	69.27	191,480	58.68	54.98	32.26
035	108,159	40.14	40.11	16.10	104,073	35.14	35.13	12.34
039	204,000	57.52	57.33	32.98	235,600	76.64	72.98	55.93

[a]Source: Survey of Tennessee Meat Packing and Processing Industry conducted as a part of this study, April-May, 1976

Table 5.7 Frequencies and average efficiency of measures of technical efficiency (TE), price efficiency (PE), and economic efficiency (EE), custom slaughterers, 1974 and 1975.

	Number of Observations					
	1974			1975		
%	TE	PE	EE	TE	PE	EE
100	7	5	4	5	6	5
90-99	4	4	3	4	3	2
80-89	2	4	3	3	3	2
70-79	1	1	2	3	3	3
60-69	2	2	1	0	0	0
50-59	1	0	1	1	0	3
Below 50	0	1	3	1	2	2
Average efficiency percentage	88.09	86.11	77.97	85.79	85.35	76.21

Table 5.8 Frequencies and average efficiency of measures of technical efficiency (TE), price efficiency (PE), and economic efficiency (EE), commercial slaughterers, 1974 and 1975.

%	Number of Observations					
	1974			1975		
	TE	PE	EE	TE	PE	EE
100	4	4	4	6	4	4
90-99	2	3	1	1	1	1
80-89	5	3	2	0	2	2
70-79	3	4	0	5	4	0
60-69	2	2	5	3	4	1
50-59	5	5	2	4	3	2
Below 50	2	2	9	4	5	13
Average efficiency percentage	76.23	75.01	60.74	72.28	70.63	55.20

technically efficient in the composite approach analysis. The five technically efficient custom slaughterers, however, were technically efficient only relative to other firms in that group. Average technical efficiency in 1975 for the custom slaughterers was about 86 percent (Table 5.7), and about 72 percent for the commercial slaughterers (Table 5.8).

Price Efficiency Indexes, 1974 and 1975

In 1974, five custom slaughterers and four commercial slaughterers were 100 percent efficient in their adjustments to factor prices faced by the individual firm (Tables 5.5 and 5.6). The 100 percent price efficient commercial slaughterers were also 100 percent price efficient in the composite analysis for 1974. The five 100 percent price efficient custom slaughterers were rated relative to other firms in their group of firms. Average price efficiency of the custom slaughterers was about 86 percent in 1974 (Table 5.7), and about 75 percent for the commercial slaughterers in the sample (Table 5.8).

Six custom slaughterers and four commercial slaughterers were 100 percent price efficient in 1975. The four 100 percent price efficient commercial slaughterers were also 100 percent price efficient in the composite analysis for 1975. The six 100 percent price efficient custom slaughterers were rated relative to other firms in the custom slaughtering classification. Average price efficiencies for the custom and commercial slaughterers in 1975 were about 85 percent and 71 percent, respectively (Tables 5.7 and 5.8).

Economic Efficiency Indexes, 1974 and 1975

Two custom slaughterers and four commercial slaughterers were 100 percent economically efficient in 1974 (Tables 5.5 and 5.6). Average economic efficiencies for the custom and commercial slaughterers in 1974 were about 78 percent and 61 percent, respectively (Tables 5.7 and 5.8).

In 1975, two custom and four commercial slaughterers were 100 percent economically efficient (Tables 5.5 and 5.6). Average economic efficiencies in 1975 for the custom slaughterers were about 76 percent (Table 5.7), and about 55 percent for the commercial slaughterers (Table 5.8).

The Mann-Whitney rank-sum test was used to test for a significant change in the mean economic efficiency measure found for custom and commercial slaughterers for the two years of the study.

The Mann-Whitney rank-sum test indicated that the average cost of production was unchanged for the custom slaughterers in the split analysis between 1974 and 1975 (Table A.2). However, there was a significant change in the mean economic efficiency measure for commercial slaughterers in the split model between 1974 and 1975 (Table A.3). The statistical test for this group of slaughterers indicated that the average cost of production increased significantly between 1974 and 1975.

The Kruskal-Wallis rank-sum test indicated that no significant difference existed in the mean economic efficiency measure for the custom and commercial slaughterers for the first year of the study

(Table B.1). Thus, it may be assumed that the average cost of production was approximately the same for both groups of slaughterers in 1974.

However, the statistical test for a difference between the mean economic efficiency measure for the two groups of slaughterers in 1975 was significant at a confidence level of 95 percent (Table B.2). The average cost of production was significantly lower for the custom slaughterers in 1975.

CHAPTER VI

SUMMARY AND CONCLUSIONS

I. REVIEW OF THE APPROACH

The objectives of this study were to determine (1) the changes that have occurred in expenditures for energy sources, petrochemical based materials, and related items used in the Tennessee meat packing and processing industry between 1974 and 1975, (2) the effects of these changes on relative costs, efficiencies, and operating procedures and programs, and (3) if a significant change occurred in the average cost of production between 1974 and 1975.

Forty plants, including both custom slaughterers and commercial slaughterers were selected for study. Price-quantity data for each firm were obtained for five inputs: hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials.

Objective 1 was accomplished by observing the changes in expenditures per $1,000 gross sales for the five inputs in the analysis, between 1974 and 1975.

Objective 2 was accomplished by using a Farrell efficiency model. Technical, price, and economic efficiency indexes were estimated for each of the 40 firms. Average efficiency measures were calculated for the three indexes for the composite analysis.

A second analysis was used in which firms were classified according to the type of slaughtering license held. This analysis

sought to determine the effects, if any, of the changes identified in Objective 1, on custom slaughterers and commercial slaughterers when analyzed relative to other firms within their respective slaughtering plant group.

Objective 3 was accomplished by calculating 1974 and 1975 economic efficiency ratings for the firms in the sample. Firms that were 100 percent economically efficient had the minimum observed average costs of production, based on the variables included in the study. The mean economic efficiency ratings for 1974 and 1975 were tested for a significant change in order to detect a change in the average costs of production.

II. CONCLUSIONS

Expenditures per $1,000 gross sales were calculated for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials. Thirty firms paid more for hired labor in 1975 than in 1974; 32, 19, 27, and 30 paid more for electricity, water and sewage service, natural gas, and supplies and cleaning materials, respectively.

The mean economic efficiency ratings for slaughterers in the composite analysis were tested to determine if a significant change occurred in the minimum average costs of production between 1974 and 1975. The mean economic efficiency ratings were equivalent to the inverse ratios of average costs of production. As such, a significant change in the mean economic efficiency rating would suggest that a significant change occurred in the minimum average costs of production.

In the composite analysis, it was found that no significant change occurred in the mean economic efficiency ratings between 1974 and 1975.

The mean economic efficiency rating for firms in the subsamples created in the "split" analysis, also was tested for a significant change between the two years under study. The change in economic efficiency ratings for custom slaughterers were statistically insignificant between 1974 and 1975 when firms in this group were evaluated separately.

However, a significant decrease in the mean economic efficiency rating for commercial slaughterers occurred between 1974 and 1975. It was concluded that the minimum average cost of production for commercial slaughterers increased significantly between the two years of the study.

Mean economic efficiency ratings for custom and commercial slaughterers were tested for both 1974 and 1975 in an attempt to determine if a significant difference existed in either year between the average costs of production of the two subsamples of firms. No statistically significant difference was found between mean economic efficiency ratings of the two groups of firms in 1974. However, the mean economic efficiency rating for the seventeen custom slaughterers, as a group, was significantly higher than the mean economic efficiency rating for the twenty-three commercial slaughterers in 1975. This suggested that the custom slaughterers were affected more by increased costs of the five inputs included in the analysis.

III. IMPLICATIONS FOR OPERATING PROCEDURES AND PROGRAMS

A considerable variation was noted in expenditures per $1,000 gross sales for the five inputs included in the analysis. Likewise, technical, price, and economic efficiencies varied widely between the most efficient firms and those firms that were highly inefficient in their adjustments to factor proportions and factor prices.

This suggested that many firms were operating with average costs that were in excess of the observed minimum demonstrated by the firms with 100 percent economic efficiency ratings. Therefore, it can be concluded that proper conservation measures with regard to utilization of energy sources, petrochemical based materials, and related inputs will result in improved efficiencies. In the same manner, adjustments to factor price relationships are possible for firms whose price efficiency indexes were less than 100 percent.

BIBLIOGRAPHY

BIBLIOGRAPHY

Aigner, D. J., and S. F. Chu. "On Estimating the Industry Production Function." American Economic Review, 58:826-839. September, 1968.

American Gas Association. A. G. A. Rate Schedule. American Gas Association, Inc. New York, N. Y., June, 1974.

Berry, John H. "The Energy Problem and Agricultural Production." Western Agricultural Economics Association, 1974 Proceedings. Moscow, Idaho, July, 1974, pp. 195-200.

Boles, James N. "Efficiency Squared--Efficient Computations of Efficiency Indexes." Western Farm Economics Association, 1966 Proceedings. Pullman, Washington, January, 1967, pp. 137-142.

_____. The 1130 Farrell Efficiency System--Multiple Products, Multiple Factors. Giannini Foundation of Agricultural Economics. Berkeley, California, February, 1971.

Bressler, R. G. "Efficiency in the Production of Marketing Services." Economic Efficiency Series, Paper No. 6. Social Science Research Council Project in Agricultural Economics. Chicago: University of Chicago, 1950.

_____. "The Measurement of Productive Efficiency." Western Farm Economics Association, 1966 Proceedings. Pullman, Washington, January, 1967, pp. 129-136.

Farrell, M. J. "The Measurement of Productive Efficiency." Journal of Royal Statistical Society, Series A, Part III, 120:253-281, 1957.

Farrell, M. J., and M. Fieldhouse. "Estimating Efficient Production Functions Under Increasing Returns to Scale." Journal of Royal Statistical Society, Series A, Part II, 129:252-267, 1962.

Ferguson, C. E. Microeconomic Theory, Revised Edition. Homewood: Richard D. Irwin, Inc., 1969.

Freund, John E. Modern Elementary Statistics, Third Edition. Englewood Cliffs: Prentice-Hall, Inc., 1967.

Futures, vol. 177, p. 331. Cited by D. Pimental, Science (November 2, 1973), p. 443.

Hopkins, Robert John. "The Wholesome Meat Act and the Livestock-Meat Industry." Unpublished Ph.D. dissertation, University of Tennessee, Knoxville, 1972, p. 19.

Lau, Lawrence J., and Pan A. Yotopoulos. "A Test for Relative Economic Efficiency: Some Further Results." American Economic Review, 63:213-223, 1973.

Lloyd, W., and E. J. Opryszek. "How to Save Energy in a Meat Plant." Meat Industry, vol. 22, No. 2, February, 1976, pp. 25-27.

Meat Industry. "Conserving Energy," vol. 21, No. 4, April, 1975, pp. 20-22.

Nerlove, Marc. Estimating and Identification of Cobb-Douglas Production Functions. Chicago: Rand McNally, Inc., 1965.

O'Conner, C. W., and T. M. Hammonds. "Measurement of the Economic Efficiency of Central-Fabrication versus Carcass-Meat Handling Systems." American Journal of Agricultural Economics, 57:665-675, 1975.

Pimental, D., L. E. Hurd, A. C. Bellotti, M. J. Forster, I. N. Oka, O. D. Sholes, and R. J. Whitman. "Food Production and the Energy Crisis." Science, vol. 182 (November 2, 1973), pp. 443-449.

Report to Program on Policies for Science and Technology in Developing Nations. Cited by D. Pimental, Science, p. 443. Glasgow: University of Strathclyde, 1972.

Sanders, Adolph, T. L. Frazier, and J. H. Padgett. "An Appraisal of Economic Efficiencies Within Livestock Slaughtering Plants." Georgia Agricultural Experiment Station Bulletin, N. S. 122, 1964.

Seitz, W. D. "Efficiency Measures for Steam-Electric Generating Plants." Western Farm Economics Association, 1966 Proceedings. Pullman, Washington, January, 1967, pp. 143-151.

_____. "The Measurement of Efficiency Relative to a Frontier Production Function." American Journal of Agricultural Economics, 52:505-511, 1970.

_____. "The Measurement of Productive Efficiency." Unpublished Ph.D. dissertation, University of California, Berkeley, 1968.

Sitorus, B. L. "Productive Efficiency and Redundant Factors of Production in Traditional Agriculture of Underdeveloped Countries." Western Farm Economics Association, 1966 Proceedings. Pullman, Washington, January, 1967, pp. 153-158.

Tennessee Department of Agriculture. Directory 1974. Division of Food and Drugs, Nashville, Tennessee, 1974.

Tennessee State Planning Office. Sanitary Services in Tennessee. Nashville, Tennessee, July, 1975.

Timmer, C. Peter. "On Measuring Technical Efficiency." Food Research Institute Studies in Agricultural Economics, Trade, and Development. 9:97-171, Stanford, California, 1970.

United States Department of Labor, Bureau of Labor Statistics. Employment and Earnings, States and Areas, 1939-1975. Washington, D. C.: United States Government Printing Office, January, 1976.

United States Federal Power Commission. Typical Electric Bills, 1973-1975. Washington, D. C.: United States Government Printing Office, January, 1976.

APPENDICES

APPENDIX A

THE MANN-WHITNEY TEST

The Mann-Whitney rank-sum test is the nonparametric alternative to the two-sample t-test. This test is based on the sum of ranks assigned to the observations of either sample in which the combined data are ranked according to size.

Using rank sums, the test is based on the statistic:

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_A$$

where,

n_1 = size of first sample

n_2 = size of other sample

R_A = sum of ranks assigned to the values of the first sample.

The mean and standard deviation of the sampling distribution of U is approximated by:

$$\mu_U = \frac{n_1 n_2}{2}$$

$$\sigma_U = \frac{n_1 n_2 (n_1 + n_2 + 1)}{12}$$

where,

μ_U = mean of sampling population of U

σ_U = standard deviation of sampling population of U.

If n_1 and n_2 are both greater than 10, the sampling distribution of U can be approximated closely by the normal distribution. Therefore,

the null hypothesis that the means of the two populations are equal (against the alternative hypothesis that the means of the two populations are unequal) can be rejected if:

$$z = \frac{U - u_U}{\sigma_U}$$

is less than $-z_{\alpha/2}$ or exceeds $z_{\alpha/2}$ wnere α is the level of significance.

The Mann-Whitney rank-sum test for a significant change in the mean economic efficiency measure for the forty observations, between 1974 and 1975, is contained in Table A.1.

Table A.2 contains the Mann-Whitney rank-sum test for the custom slaughterers. The test is used to detect a significant change in the mean economic efficiency for the seventeen custom slaughterers between 1974 and 1975.

Table A.3 contains rank-sum data for the twenty-three commercial slaughterers. The test is used to detect a significant change in the mean economic efficiency measure for the commercial slaughterers when analyzed individually for the two years of the study.

Table A.1 The Mann-Whitney rank-sum test for a change in the mean economic efficiency measure, composite analysis, 1974 and 1975.

B	A	B	A	A	B	B	A	A	B	B
(5.57)	(5.75)	(8.78)	(9.10)	(12.13)	(12.34)	(12.75)	(13.01)	(16.10)	(16.11)	(16.53)
A	B	B	A	A	B	A	B	B	A	B
(17.45)	(17.56)	(17.88)	(18.84)	(18.86)	(19.36)	(21.67)	(21.67)	(22.13)	(22.48)	(22.68)
B	B	A	A	B	B	A	A	A	B	A
(24.94)	(24.94)	(25.92)	(27.36)	(27.71)	(27.73)	(27.78)	(28.83)	(29.24)	(31.90)	(31.98)
B	A	A	A	B	A	B	B	A	B	B
(32.26)	(32.80)	(32.98)	(33.75)	(33.82)	(33.94)	(35.68)	(37.49)	(39.94)	(41.02)	(42.04)
A	A	A	B	B	B	B	A	B	A	A
(43.44)	(44.12)	(44.48)	(45.66)	(48.54)	(48.63)	(49.38)	(50.41)	(52.08)	(52.41)	(54.09)
B	B	A	B	B	A	B	A	A	A	A
(54.47)	(55.11)	(57.62)	(58.88)	(60.19)	(60.71)	(60.86)	(66.90)	(68.33)	(69.28)	(69.82)
A	B	B	A	A	B	B	A	B	A	A	B
(81.00)	(81.24)	(83.41)	(97.16)	(97.22)	(99.95)	(100)	(100)	(100)	(100)	(100)	(100)
A	B										
(100)	(100)										

$n_A = 40$ $R_A = 1663.5$ $z_{cr} = 0.4750$

$n_B = 40$ $z = 0.4186$

A = 1974 efficiency measures

B = 1975 efficiency measures

Table A.2 The Mann-Whitney rank-sum test for a change in the mean economic efficiency measure, custom slaughterers, 1974 and 1975.

B (16.62)	B (25.87)	A (26.21)	A (38.96)	A (43.36)	B (51.03)	A (54.17)	B (54.71)	B (58.49)	A (67.12)	B (74.30)
A (76.86)	B (76.95)	B (77.20)	A (79.47)	A (81.56)	B (81.68)	B (81.71)	A (82.32)	A (85.81)	A (93.74)	A (97.61)
B (98.12)	A (98.24)	B (98.91)	B (100)	A (100)	B (100)	A (100)	B (100)	A (100)	B (100)	A (100)	B (100)

$n_A = 17$ $R_A = 300$ $z_{cr} = 0.4750$

$n_B = 17$ $z = 0.0861$

A = 1974 efficiency measures

B = 1975 efficiency measures

Table A.3 The Mann-Whitney rank-sum test for a change in the mean economic efficiency measure, commercial slaughterers, 1974 and 1975.

B (12.24)	A (16.10)	B (16.53)	B (17.56)	A (21.67)	B (22.69)	B (24.94)	A (27.78)	A (28.83)	A (31.98)	B (32.26)
A (32.98)	A (33.75)	B (33.82)	B (35.68)	A (39.94)	B (41.36)	A (43.44)	B (45.67)	B (48.54)	B (48.63)	B (49.38)
A (52.41)	B (55.93)	A (57.62)	B (58.88)	A (60.71)	B (60.86)	A (66.90)	A (68.33)	A (69.27)	A (69.82)	A (81.00)
B (81.24)	B (83.41)	A (87.22)	A (97.16)	B (99.95)	B (100)	A (100)	B (100)	A (100)	A (100)	B (100)	A (100)
B (100)										

$n_A = 23$ $R_A = 566$ $z_{cr} = 0.4750$

$n_B = 23$ $z = 0.5604$

A = 1974 efficiency measures

B = 1975 efficiency measures

APPENDIX B

KRUSKAL-WALLIS TEST

The Kruskal-Wallis rank-sum test, also called the H test, is used to test the null hypothesis that the custom and commercial slaughterers came from identical populations against the alternative that the mean economic efficiency measures for the two subsamples are unequal.

This nonparametric alternative to the one-way analysis of variance, ranks the combined data according to size and sums the ranks for the observations of either sample.

The test is based on the statistic:

$$H = \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{R^2_i}{n_i} - 3(n+1)$$

where,

H = chi-square with k - 1 degree of freedom

$n = n_1 + n_2 + \ldots\ldots n_k$ observations

R_i = sum of the ith efficiency measure

i = 1, 2, ... k efficiency measures

If the null hypothesis is true and the sample size for each subsample is at least of size 5, the sampling distribution can be approximated with the chi-square distribution with k − 1 degree of freedom. The null hypothesis can be rejected at a significance level of α if H exceeds χ^2 for k − 1 degree of freedom.

Table B.1 contains the rank-sum data for the custom and commercial slaughterers in 1974 when each subsample was analyzed relative to other slaughterers in their own classification.

Table B.2 contains the rank-sum data for the custom and commercial slaughterers in 1975. Again, each subsample was analyzed relative to the firms in the subsample made up of commercial slaughterers.

Table B.1 Kruskal-Wallis rank-sum test for a significant difference in the mean economic efficiency measure for custom and commercial slaughterers, 1974.

B (16.10)	B (21.67)	A (26.21)	B (27.78)	B (28.83)	B (31.98)	B (32.98)	B (33.75)	A (38.96)	B (39.94)	A (43.36)
B (43.44)	B (52.41)	A (54.17)	B (57.62)	B (60.71)	B (66.90)	A (67.12)	B (68.33)	B (69.27)	B (69.82)	A (76.86)
A (79.47)	B (81.00)	A (81.56)	A (82.32)	A (85.81)	B (87.22)	A (93.74)	B (97.16)	A (97.61)	A (98.24)	B (100)
A (100)	B (100)	B (100)	A (100)	A (100)	B (100)	A (100)				

$n_A = 17$ $R_A = 418$ $\chi^2 = 3.841$

$n_B = 23$ $R_B = 402$ $\chi^2 cr = 3.6756$

A = custom slaughterer efficiency measures

B = commercial slaughterer efficiency measures

Table B.2 Kruskal-Wallis rank-sum test for a significant difference in the mean economic efficiency measure for custom and commercial slaughterers, 1975.

B (12.34)	B (16.53)	A (16.62)	B (17.56)	B (22.69)	B (24.94)	A (25.87)	B (32.26)	B (33.82)	B (35.68)	B (41.36)
B (45.67)	B (48.54)	B (48.63)	B (49.38)	A (51.03)	A (54.71)	B (55.93)	A (58.49)	B (58.88)	B (60.86)	A (74.30)
A (76.95)	A (77.20)	B (81.24)	A (81.68)	A (81.71)	B (83.41)	A (98.12)	A (98.91)	B (99.95)	B (100)	A (100)
B (100)	A (100)	B (100)	A (100)	A (100)	B (100)	A (100)				

$n_A = 17$ $R_A = 424$ $\chi^2 = 3.841$

$n_B = 23$ $R_B = 396$ $\chi^2_{cr} = 4.2667$

A = custom slaughterer efficiency measures

B = commercial slaughterer efficiency measures

APPENDIX C

REPORTED EXPENDITURES FOR INPUTS

Total dollar expenditures for inputs by each firm in the sample in 1974 and 1975 are reported in Tables C.1 and C.2. Output is measured in gross sales of product.

Table C.1 Reported expenditures for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials, gross sales used as a measure of output, 1974.[a]

Observation	Output	Hired Labor	Electricity	Water and Sewage Service	Natural Gas	Supplies and Cleaning Materials
001	52,661	8,670	756	245	608	4,275
002	617,000	47,500	3,185	426	2,128	29,470
003	48,286	5,850	780	210	340	4,426
004	39,074	8,678	890	310	438	3,832
005	52,812	5,633	3,248	196	411	8,247
006	141,816	13,410	4,286	150	514	13,480
007	1,248,103	55,704	3,845	400	1,827	65,913
008	336,000	68,000	4,800	185	1,228	27,900
009	219,670	43,580	4,355	317	606	18,670
010	48,028	2,130	720	150	450	4,150
011	63,500	15,500	1,985	271	450	6,870
012	443,000	37,496	5,721	586	2,097	33,921
013	1,359,595	104,147	4,459	616	1,106	69,073
014	109,300	13,000	1,716	420	1,190	8,000
015	199,133	34,255	4,197	740	2,240	11,202
016	400,000	45,380	9,800	650	8,400	24,500
017	244,000	46,500	5,422	457	1,536	27,000
018	50,000	12,000	2,527	240	800	3,500
019	1,349,288	254,378	5,012	1,560	1,771	68,978
020	1,415,594	154,570	10,178	1,528	7,637	84,732
021	84,212	9,623	1,331	168	447	4,350
022	354,510	68,000	2,355	628	1,664	24,197
023	386,655	45,000	3,140	204	925	26,160
024	92,110	11,900	1,773	171	690	6,421
025	406,000	23,250	2,350	236	1,088	18,878
026	150,000	28,000	2,500	119	1,500	15,000
027	28,684	3,020	2,320	148	174	3,119
028	128,977	9,211	1,545	163	1,221	8,780
029	286,818	31,820	3,491	869	2,290	24,662
030	28,101	5,120	1,678	118	638	4,440
031	93,280	7,850	860	120	300	8,823
032	198,000	23,119	3,266	604	1,841	11,016
033	184,200	33,848	3,119	638	1,229	10,290
034	96,078	3,534	2,496	196	2,750	18,400
035	108,159	12,028	1,342	160	916	17,396
036	108,000	15,320	1,720	118	820	8,620
037	31,776	7,650	1,117	121	440	6,160
038	204,000	24,386	3,883	284	1,294	12,896
039	82,330	18,416	2,163	186	516	6,678
040	37,190	4,600	1,712	342	535	5,600

[a]Source: Survey of Tennessee Meat Packing and Processing Industry, conducted as a part of this study, April-May, 1976.

Table C.2 Reported expenditures for hired labor, electricity, water and sewage service, natural gas, and supplies and cleaning materials, gross sales used as a measure of output, 1975.[a]

Observation	Output	Hired Labor	Electricity	Water and Sewage Service	Natural Gas	Supplies and Cleaning Materials
001	58,402	8,833	1,095	251	639	5,460
002	596,000	53,750	4,096	387	2,642	28,100
003	57,185	6,345	1,115	186	408	5,323
004	35,499	9,018	1,221	478	658	4,686
005	46,965	5,261	3,353	242	509	7,176
006	128,114	16,098	5,806	150	490	15,590
007	1,251,028	61,664	5,436	400	2,491	71,921
008	594,000	98,000	5,200	265	1,870	36,233
009	154,890	36,875	4,510	266	618	19,126
010	51,916	3,670	1,175	150	600	4,540
011	83,811	21,621	2,290	277	633	8,473
012	420,818	39,680	6,188	638	1,381	28,288
013	1,112,412	105,440	4,667	717	1,287	72,076
014	191,000	26,000	6,600	420	1,375	14,000
015	183,762	47,400	4,066	760	2,540	13,473
016	365,000	48,920	10,200	750	8,700	25,500
017	286,000	49,000	8,750	450	1,164	35,000
018	35,000	15,000	3,510	150	800	5,000
019	1,257,400	275,757	5,687	1,680	2,387	73,326
020	1,561,211	197,136	14,550	1,466	6,821	99,393
021	79,922	10,278	1,693	173	616	6,677
022	406,560	87,750	3,119	613	2,009	30,447
023	506,416	55,000	3,510	224	1,180	38,483
024	88,600	12,500	2,416	186	838	8,440
025	450,000	25,863	3,125	218	1,190	24,120
026	125,000	26,000	3,600	134	1,500	17,000
027	20,542	2,416	1,476	154	142	3,362
028	143,816	12,190	1,820	124	1,417	14,847
029	352,212	46,904	5,623	920	3,347	28,098
030	45,835	6,090	2,400	134	698	5,192
031	113,000	8,820	1,140	126	350	13,287
032	224,500	27,040	4,004	590	2,190	15,412
033	191,480	36,290	3,688	687	1,486	16,629
034	78,554	3,539	3,180	210	2,249	17,324
035	104,073	14,602	1,839	197	819	19,619
036	76,315	14,890	2,150	102	886	8,880
037	27,236	8,126	1,270	129	560	5,890
038	235,600	29,223	4,116	297	1,517	15,080
039	74,590	17,396	3,004	197	489	4,819
040	42,337	5,200	1,822	304	688	7,292

[a]Source: Survey of Tennessee Meat Packing and Processing Industry conducted as a part of this study, April-May, 1976

APPENDIX D

LISTING OF CONTROL CARDS USED FOR CALCULATING EFFICIENCIES WITH THE FARRELL EFFICIENCY ALGORITHMS

```
          PROGRAM
          INITIALZ
          TITLE ('                              ')
          MOVE (XDATA,'MTPACKERS')
          MOVE (XPBNAME, 'PBFILE')
          CONVERT ('SUMMARY')
          BCDOUT
          SETUP ('MAX')
          MOVE (XOBJ,'COST')
          MVADR (ALL,FIRST)
          PICTURE
          TRANCOL
          GOTO (LOOP)
MORE      RESTORE
          TALLY (COUNT,LOOP)
          GOTO (OUT)
LOOP      MVIND (XRHS,ALL,4)
          PRIMAL
          SAVE
          SOLUTION ('ACTIVE')
          ALL=ALL+4
          GOTO (MORE)
OUT       EXIT
ALL       DC(0)
COUNT     DC(40)
FIRST     DC ('B001','B002','B003','B004','B005','B006','B007','B008',  X
'B009','B010','B011','B012','B013','B014','B015','B016','B017','B018',  X
'B019','B020','B021','B022','B023','B024','B025','B026','B027','B028',  X
'B029','B030','B031','B032','B033','B034','B035','B036','B037','B038',  X
'B039','B040')
          PEND
```

VITA

Stanley E. Pendlum was born in Mansfield, Ohio, on December 9, 1948. He graduated from Olive Hill High School, Olive Hill, Kentucky, in May, 1966. In September of that year, he entered Morehead State University, Morehead, Kentucky, and was graduated with a Bachelor of Science in General Agriculture in June, 1970.

He served 46 months with the United States Air Force before entering Graduate School at the University of Tennessee at Knoxville in September, 1974. Requirements for the degree of Master of Science in Agricultural Economics and Rural Sociology were completed in December, 1976.