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Title: MEASUREMENT OF THE ECONOMIC EFFICIENCY OF SELECTED VERTICALLY COORDINATED MEAT HANDLING SYSTEMS

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Technological change in the distribution of wholesale beef to retail stores has received considerable attention in recent years. Beef, which traditionally has moved through the system in carcass form, is now being centrally fabricated at the packer or wholesale level. The fabricated system has several advantages, which *a priori* indicate that retail firms which utilize this new system should be relatively more efficient than firms which use carcass beef. However, there is little public information concerning the relative efficiencies of retail stores using the two systems. The purpose of this thesis is to examine conceptually and empirically the relative technical, pricing and economic efficiency of sample retail stores which use these two beef handling systems in the Pacific Northwest.

Two conceptual models, both based on microeconomic production theory, are employed to estimate each of the relative efficiency measures. The frontier approach provides a direct estimate of a frontier production surface. Once the surface is estimated, the relative efficiency of each firm is easily computed. An alternative model is the profit function which assumes profit maximization by each firm. By duality, each convex profit function has a concave production function, and vice versa. Therefore, without loss of generality, relative efficiency is estimated using only profit functions.

Measurement of the Economic Efficiency of Selected Vertically Coordinated Meat Handling Systems

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I. INTRODUCTION

Meat, Economics and Efficiency

There is new excitement in the packer-retail segment of the beef distribution system in the United States. This industry, which claims to traditionally be a low profit business (Vignieri, 1971), anticipates that a change in technology will be the ray of hope they have awaited to improve profits. However, some firms which have adopted this new technology have not increased profits. This phenomenon poses the felt need toward which this study is directed. Can any inference be made concerning firms which have adopted the new technology and those that have not, relative to their efficiencies?

Microeconomic theory provides a foundation upon which to build a conceptual model to analyze this question. Most economic models which purport to explain the production process, have as their basis, the maximization of some function, by an economic unit, subject to a set of constraints. This study will not be different. The firm is the economic unit, and the degree to which the firm maximizes net revenues subject to product prices and a particular production function is a measure of relative efficiency.

There are at least three measures of inefficiency which conform to economic theory, when the firm's maximization process fails. One general measure considers whether the firm or firms under comparison have excessive average costs as compared to the firm or firms with the lowest average costs. This relative measure of maximization is commonly referred to as economic efficiency.

The second and third measures of inefficiency are partial explanations of economic inefficiency. That is, economic efficiency can be disaggregated into two components: allocative efficiency and technical efficiency.

When a firm fails to operate where the marginal revenue product of all factors of production is equal to their marginal cost, the firm is said to be pricing inefficient. This inefficiency can occur for several reasons, including inadequate information, institutional constraints, differences in the relative entrepreneurial ability of management, or the use of a decision rule other than the first order conditions of profit maximization.

The third cause of inefficiency, or failure to maximize, may be the result of the firm failing to produce on the technical production frontier that yields the greatest output for any given set of inputs. This phenomenon is referred to as technical inefficiency. Some possible sources of technical inefficiency could be inefficient management, the existence of different technologies within an industry, the existence of economies related to scale, or the existence of non-homogenous inputs.

It was not until the 1950's that these three measures of efficiency, as a group, received much attention from economists. That is, traditional work in the production theory of the firm described efficient techniques, but the process by which those techniques were discovered, failed to be examined. However, with the advent of linear programming, the door to the firm was opened, and the internal allocative decisions became subject to as much scrutiny as the external results of the firms management decisions. Walters, reiterates this, by pointing out that,

> . . . in recent times it has been recognized that the problems of resource allocation within firms are closely analogous to those between firms and industries. There is both economy and additional insight to be gained by pushing the domain of study back to the firm to explain its internal decisions (Walters, 1963, p, 2).

This study uses the firm and the theory of production to look at technical, pricing and economic efficiency of alternative retail marketing systems of fresh meat.

Retail Meat Systems[1/]

With the advent of the supermarket, meat wrapped in cellophane packages replaced the butcher shop. Consumers generally accepted this as a standard operating procedure. The advantages of greater volume and expanded shelf life made this type of marketing system attractive to retailers as well. Also, new methods employing assembly line cutting techniques expanded the output per skilled meat cutter. New methods allowed persons possessing fewer skills to handle certain types of cuts. In essence, the economic efficiency of the retail market was increased. This general concept of meat preparation and merchandising still pervades the retail segment of the industry, today.

This paper is primarily concerned with the meat department of a retail grocery store. However, alternative distribution systems that begin at the packer level and proceed through the retail store, will serve as a method of stratifying retail stores so that relative efficiencies can be measured.

All red meats do not move through these systems in the same physical form. The hog-pork sector is unique in that approximately one-half of the retail pork sold is in a cured or processed form.

[1/] Much of the information in this section is summarized from J. Russell Ives, The Livestock and Meat Economy of the United States (1966).

Retailers receive the majority of their fresh pork in primal cut form.[2/] This distribution system is consistent for almost all retail stores in the United States.

Beef, on the other hand, is sold almost entirely as fresh meat, with approximately one-half being delivered to the retailer in carcass form (Shaw and Christensen, 1973). Presently, the beef sector is undergoing changes which include increased retailer purchases of primal or fabricated[3/] cuts instead of carcasses. Retailers have also been experimenting with central cutting, packaging and pricing of retail cuts. Experiments with freezing of retail cuts have also taken place in the meat trade since 1950.[4/] These changes in the retail procurement practices of beef serve as the catalyst for comparison of alternative marketing systems in this study.

Most of the changes in the meat system seem to focus on decreasing production costs. _A priori,_ certain characteristics of the present systems seem to encourage these types of changes. First,

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[2/] Primal cuts can be defined as parts of a carcass that are sold separately. In the case of fresh pork, the common primals are loins, spare-ribs and butts.

[3/] Fabricated cuts are primals which have been trimmed and processed so that a minimum of functions at the retail store are necessary to produce retail cuts for the consumer.

[4/] Specific information about frozen meat distribution systems can be found in Tuma _et al_. (1973) and Youde and O'Connor (1973).

the carcass must be handled a number of times at each distribution point. The carcass is not of a convenient form or weight to be handled easily.

Second, the entire cutting operation takes place at the retail market. There is a small weight loss due to shrinkage at the packer level, but there is a massive weight loss due to trimming and waste at the retail store. This has some important implications for technical efficiency of firms as well as for transportation costs and government regulations concerning sanitation and the utilization of the trim for meat by-products.

Third, cutting the carcass at the retail store also has certain implications concerning economies of scale. Levels of production within retail stores are usually limited by business volume, rather than by space or capital equipment. This often creates an over-capacity situation in the meat department.

Fourth, and finally, when the retail store processes a full carcass, it commits itself to selling both popular and unpopular cuts of beef. This may become acute in areas that have highly regional or ethnic consumer purchasing characteristics.

On the basis of these possible weaknesses of the present system, several studies are available suggesting certain changes of the meat production and distribution system.[5/] These studies emphasize the institutional aspects of the industry itself as a primary reason for high costs. Suggestions were made concerning the location of both meat processing personnel and their equipment within a system. These suggestions were generally based on average cost comparisons of alternative systems. Only the Cornell study (Weatherly et al., 1967) considered the effect of economies of scale.

Statement of the Problem

Technological change in the distribution of wholesale beef to retail stores, and the rate of acceptance of this change, has received considerable attention in recent years. In 1966, fabricated beef was an idea in its infancy. By 1969, there appeared to be a marked trend to centralized fabrication, and today, over one-half of the beef shipped to supermarkets is centrally pre-fabricated. For an industry that had not changed its technology to any great degree since the 1920's, this change to fabricated beef has been revolutionary. Fabricated beef has advantages and problems, both of which are reviewed by Shaw and Christensen (1973). Most research on the

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[5/] These studies are numerous, and will not be specifically reviewed here. Some of the studies that are most applicable to this topic area are: Hoecker (1963); A.T. Kearney Co. Inc., (1969); Weatherly et al. (1967); Erickson and Litchty (1972); Duewer and Maki (1966); and Maki and Crom (1965).

comparison of carcass and fabricated systems estimate average cost per pound, and fail to attempt to explain where any deviation from a minimum cost originates. That is, the relative economic efficiency between systems has been explored, but technical and pricing efficiency has been ignored.

For the firm, knowing the source of any inefficiency may help considerably in management decisions. A priori, many characteristics of the fabricated system seem to indicate that it may have a relatively greater technical efficiency than the carcass system. There seems to be little evidence leading to any prior estimates of the relative pricing efficiency between the systems. The problem then is that there is a lack of public knowledge concerning the physical and pricing efficiency of alternative retail meat procurement systems.

If rational decisions are to be reached by retail management, it is important that a framework for positive analysis be available. If the economist chooses to fulfill this role, he must first develop a framework which is relevant for considering those economic implications that he or others feel are important. An appropriate framework for analysis must yield meaningful results that are useable by the decisionmaker.

Such is the purpose of this study. Technical, pricing and economic efficiencies of selected alternative procurement systems by retail stores are considered. A framework for analysis is developed which permits the identification of each type of efficiency. This framework is then applied to two specific topics of interest to the retail meat industry; (1) the effect of change in technology and (2) the effect of scale of operation. Although the expressed purpose is aimed toward the meat industry, the framework would be useful for exploring a wide variety of marketing problems.

Purposes and Objectives of the Study

This study is a portion of a regional research program designed to provide an interdisiplinary body of knowledge dealing with the marketing of beef. The overall objective is to evaluate the technical and structural changes in beef marketing.

It is the specific purpose of this dissertation to examine conceptually and empirically the efficiency of alternative meat handling systems of retail grocery stores in the Pacific Northwest. To these ends the following objectives are outlined:

1. To delineate the major alternative distribution systems for beef currently in use by the wholesale-retail sector of the beef industry in the Pacific Northwest.
2. To determine a theoretical framework which will enable explicit identification of efficiency measures of sample retail meat firms in the Pacific Northwest.

3. To estimate empirically the relative technical, pricing and economic efficiency of retail meat firms in the sample.
4. To determine the simultaneous effect of size and type of distribution system on the efficiency indices of the firms.

II. THEORETICAL FRAMEWORK

The Frontier Approach to Measuring Efficiency

Production Theory of the Firm

Microeconomic production theory holds that a firm's production function specifies the maximum output attainable from a set of inputs, given the technology available to the firm (Henderson and Quandt, 1958, p. 44).[6/] Many techniques of production may be available to the firm, but it is assumed that, given the firm's cost constraint, the firm will use the production technology representing the maximum possible output that can be produced by any given combination of factors.[7/] To illustrate this concept, assume two technologies exist for producing a given output (Figure 2. 1). For quantities of input less than OA', technology 1 will yield the greatest quantity of output. However, with larger quantities of input, technology 2 is the most

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[6/] This conforms to Carlson's view that a production function for the firm can be "so defined that it expresses the maximum product obtainable from the input combination at the existing state of technical knowledge" (1956, pp. 14-15).

[7/] "The production function differs from the technology in that it presupposes technical efficiency and states the maximum output obtainable from every possible input combination. The best utilization of any particular input combination is a technical, not an economic problem. The selection of the best input combination for the production of a particular output level depends upon input and output prices and is the subject of economic analysis" (Henderson and Quandt, p. 44).

technically efficient. In this case, the frontier production function, that which conforms to the economic definitions above, is the envelope OAC.

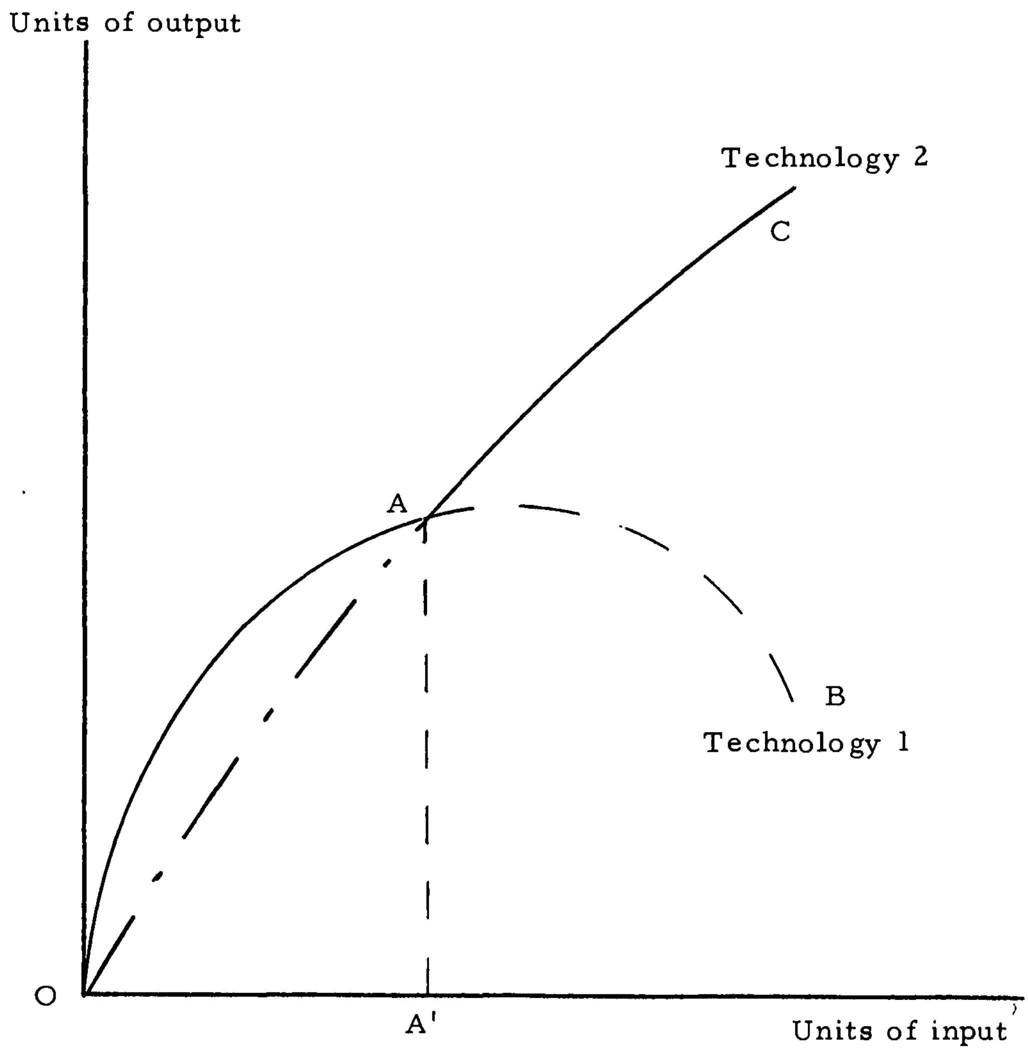

Figure 2. 1. The frontier production function: an example of two technologies of production.

This frontier production function applies to the firm, but of more interest to this study, the function conceptually holds for all other firms in the same industry. Thus, this function is often defined as the industry production function, and should be distinguished from the industry's aggregate production function, which expresses the relationship between aggregate output and the aggregate inputs of an industry.

A production function can also be shown in input space by the use of an isoquant map. An isoquant shows the different combinations of two resources with which a firm can produce equal amounts of product. Figure 2.2 is an illustration of a two input, single output case, where $Y = f(X_1; X_2)$. Along the two axes are measured the amounts of two inputs, and a point on the isoquant shows the output produced by a combination of two inputs. Each isoquant represents a different level of output and in Figure 2.2, $q_3 > q_2 > q_1$.

The marginal rate of technical substitution of X_2 for X_1 ($MRTS_{X_2, X_1}$) or the negative of the slope of the isoquant, can be defined as the amount of X_2, which will just be compensated for by an additional unit of X_1 such that the level of output does not change. Furthermore, $MRTS_{X_2, X_1}$ is equal to the marginal product of X_1 divided by the marginal product of X_2.[8/]

[8/] This can be shown mathematically as follows:

Given the production function, $Y = f(X_1, X_2)$

Marginal product is defined as the change in output (Y) for a single unit change in a variable input.

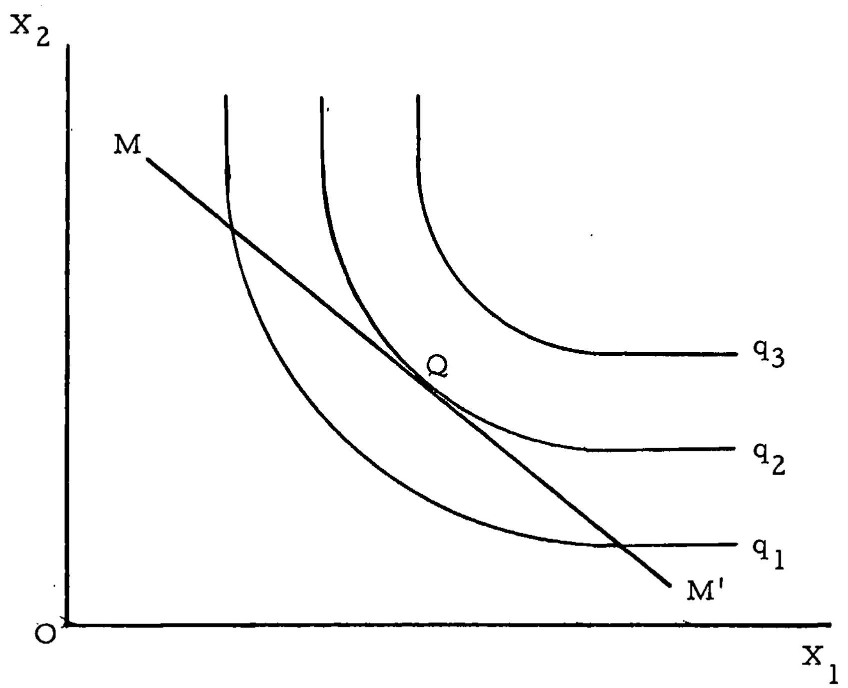

Figure 2.2. Isoquant map. Two input, one output case.

$$MRTS_{X_2, X_1} = -\frac{dX_2}{dX_1}$$

The total differential of the production function is

$$dY = \frac{\partial Y}{\partial X_1} dX_1 + \frac{\partial Y}{\partial X_2} dX_2$$

where $\frac{\partial Y}{\partial X_i}$ = marginal product of $X_i = f_i$. By setting

$dY = 0 = f_1 dX_1 + f_2 dX_2$ the

$$MRTS_{X_2, X_1} = \frac{-dX_2}{dX_1} = \frac{f_1}{f_2} .$$

Isoquants give only the maximum relationship that the firm wishes to attain, given the production function. It does not tell what the firm can do given its cost constraint. To find this, costs must be introduced. This is shown in Figure 2.2 by adding MM' to the isoquant map. The line MM' is an isocost line which shows the different combinations of inputs that the firm can purchase, given the prices of the inputs and the cost outlay available. The slope of the isocost curve equals the negative inverse ratio of the factor prices, $-P_1/P_2$.

For the firm, the problem is simple; it wishes to reach the highest isoquant, given its isocost. In Figure 2.2, this is shown by point Q, when the isocost MM' is just tangent to the isoquant SS'.[9/]

9/ This can be summarized briefly as follows:

Given $Y = f(X_1, X_2)$, constrained by $M = P_1X_1 + P_2X_2$, then using the Lagrange multiplier (λ);

$$F(X_1, X_2, \lambda) = f(X_1, X_2) + \lambda(M - P_1X_1 - P_2X_2)$$

$$\frac{\partial F}{\partial X_1} = f_1 - \lambda P_1 = 0$$

$$\frac{\partial F}{\partial X_2} = f_2 - \lambda P_2 = 0$$

$$\frac{\partial F}{\partial \lambda} = M - P_1X_1 - P_2X_2 = 0$$

Assume the second order conditions of maximization have been fulfilled, the following is true;

By assuming a linear homogeneous production function,[10/] each isoquant in Figure 2.2, can be collapsed into one, which can be defined as a unit isoquant. This is shown in Figure 2.3, where now, the two axes represent the rate of use of each input per unit of output. The curve SS' represents and efficient unit isoquant. That is, the unit isoquant shows the smallest quantity of X_2 that can be used to produce one unit of output (Y) as the amount of X_1 is varied. All points on this line and the ones above it are attainable, but points between the line SS' and the origin are not attainable. The isoquant SS', is representative of a frontier production function in input space. In the case of a linear homogeneous production function, the combination of factors for efficient production of any level of output can be found as a multiple of the unit isoquant. In addition, point Q in Figure 2.3, is analogous to the same point in Figure 2.2. That is, given the ratio of the factor prices, the slope of the isocost, the tangency of the isocost and the isoquant represents the

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$$\lambda = \frac{f_1}{P_1} \quad \text{and} \quad \lambda = \frac{f_2}{P_2}$$

$$\therefore \quad \frac{f_1}{P_1} = \frac{f_2}{P_2} \quad \text{and} \quad \frac{f_1}{f_2} = \frac{P_1}{P_2}.$$

[10/] A linear homogeneous production function implies constant returns to scale. An equal percentage increase in the quantity of each input used results in the same percentage increase in the level of output produced (i.e., a doubling of inputs will double the output).

equilibrium point of production.

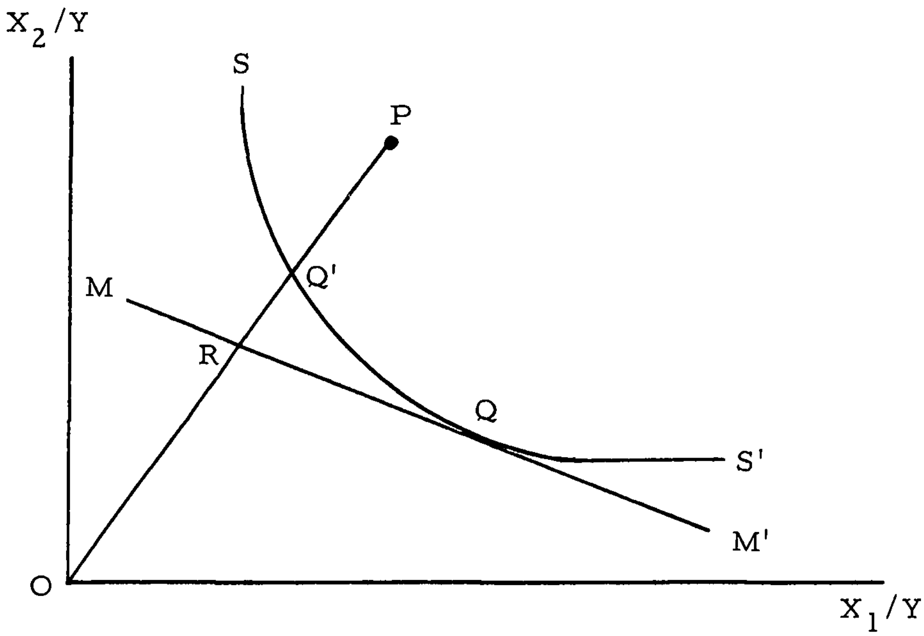

Figure 2. 3. The efficient unit isoquant for a linear homogeneous production function, and the measurement of technical, pricing and economic efficiency.

Measurement of Efficiency[11/]

Using the production theory developed above, a firm must meet two general requirements before it can be classified as efficient. First, output must be at a maximum for a given level of inputs; or stated to conform to the definition of an isoquant, the smallest amount of inputs must be used per unit of output. Second, the firm must

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[11/] Much of the information in the following three sections is summarized from Seitz (1970).

operate where the isoquant and isocost are tangent. That is, the resources must be used in the correct proportions. The first is defined as technical efficiency and the second, pricing efficiency. The product of technical and pricing efficiency is an index that is a measure of economic efficiency.

In 1957, M. J. Farrell proposed a method of obtaining the technical, pricing and economic indices. Maintaining the assumptions developed above, that of a linear homogenous production function and the characteristics of isoquants, Figure 2.3 can be used as an aid in defining the efficiency indices.

Consider a firm represented by point P. The line, OP, intersects the efficient unit isoquant (SS') at point Q'. The distance Q'P is a measure of the excess use of the two inputs relative to the most technically efficient combination possible, namely, Q'. The ratio (OQ'/OP) x 100 is a measure of technical efficiency. It can be easily seen that all points on the efficient unit isoquant are 100 percent technically efficient, and all points lying above the line (SS') are less than 100 percent efficient.

Let the prices of the inputs be represented by the isocost line MM', which is tangent to the efficient unit isoquant at point Q. It is apparent that the firm represented by point P is not using the optimum proportions of the factors of production. That is, the least-cost input combination is point Q, and any factor price line parallel to the line MM', but farther from the origin, represents a larger cost outlay for the inputs. The distance RQ' is a measure of the price inefficiency associated with the selection of the technically efficient, but more costly point Q' as compared to the minimum cost at Q. The ratio (OR/OQ') x 100 is an index of the price efficiency. The use of a production frontier separates the pricing from the technical decision, something that simple cost comparisons cannot do.

The technical and pricing efficiencies can be combined to obtain a measure of economic efficiency. This is the ratio OR/OP, and is equivalent to the product of technical and price efficiency, (OQ'/OP x OR/OQ') x 100. This measure of economic efficiency is an index of the average costs of the firms in the survey.

Estimating the Efficient Unit Isoquant

The efficient unit isoquant is the crucial element in the measurement of the three efficiency indices. The procedure to estimate this isoquant is the basic contribution made by Farrell. There are two standards which can be used as a basis in measuring a firm's efficiency. One is the theoretical standard specified by economic engineering, and the second is the best results observed in practice. Farrell points out that the theoretical standard,

> . . . is a reasonable and perhaps the best concept for the efficiency of a single production process, [but] there are considerable objections to its application to anything so complex as a typical manufacturing firm, let alone an industry (1957, p. 255).

He goes on to explain his skepticism of the theoretical standard, based on the difficulty of establishing the function in complex production processes, possible errors, the expectation that it would be "wildly optimistic", and the possibility of "unfortunate psychological effects" resulting from a plant, firm, or industry being given a low efficiency rating as a result of its use. Thus, Farrell chooses ". . . the best actually achieved [rather] than some unattainable ideal," as the basis for estimating the efficient unit isoquant (1957, p. 255).

Regression analysis is one method of estimating this "best achieved" production function. By definition, regression yields an estimate of the function that passes through the sample observations such that the sum of squared errors is minimized. This provides the average relationship between the output and the inputs, and describes the average of all firms rather than information about the most efficient firms.

On the other hand, Farrell developed a method for fitting an envelope to actual data that passes through the points nearest the origin.[12/] In Figure 2.4, the efficient unit isoquant is drawn through

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[12/] James N. Boles developed a Fortran system which significantly reduces the computation time in estimating technical efficiency (1971).

the observations for firms a, b, c, and d, and extended to infinity from points a and d. This is a "pessimistic" estimate, in that it is based on the most efficient actual performances in the sample, and additional observations will either be inefficient and not affect the envelope or will be more efficient, which will result in shifting the envelope toward the origin.

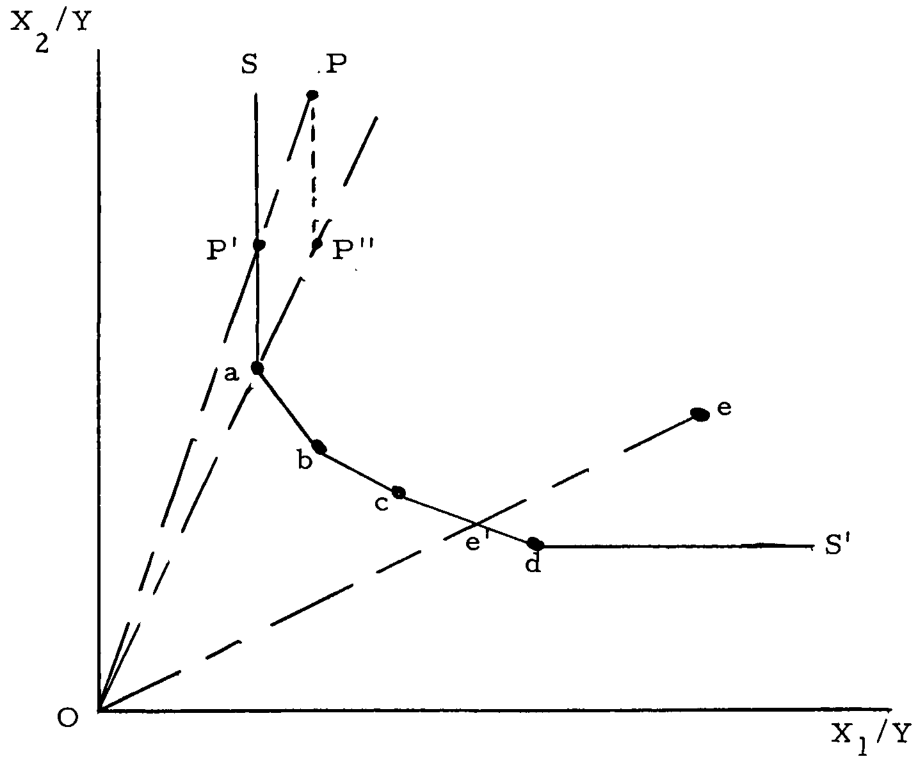

Figure 2.4. Hypothetical example of the estimate of the efficient unit isoquant.

All points not on the efficient isoquant are evaluated on the basis of linear combinations of points on the isoquant. Point e will be evaluated with reference to a weighted average of c and d. The technical efficiency is (Oe'/Oe) x 100. But what about point P? The technical efficiency for P is (OP'/OP) x 100, which is exactly the same as (Oa/OP") x 100; that is, the efficiency index for P and P" are the same. However, the firm represented by P, uses P-P" more X_1 than the firm represented by P". Points that fall into the unbounded cones, (OX_1, Od) and (OX_2, Oa) where X_1 and X_2 go to infinity, will all have a biased estimate of technical efficiency. Bressler, in discussing this peculiarity of the Farrell method states that ". . . our empirical studies suggest that a surprisingly large proportion of observations involve [this phenomenon]" (1967, p. 133). The number of cones where a biased estimate could arise is a function of the number of inputs in the model, and is equal to n*(n-1), where n is the number of inputs. The extent of the presence of this bias, and its importance in influencing the results of this model, will be examined in this study.

Scale and Efficiency

It has been assumed to this point of the discussion that constant returns to scale prevail. But, if this assumption were to be sustained, the validity of this frontier model, relative to observable characteristics in many industries, would not be readily accepted. Farrell realized this in his first paper (1957). However, he only pointed out the problem and possible solutions. Later, in 1962, Farrell and Fieldhouse considered economies of scale in detail. Sietz (1970) extended the Farrell and Fieldhouse presentation by considering the special cases of neutral and nonneutral economies of scale.

A common explanation of economies and diseconomies of scale is that output increases at a different rate than the rate of increase of a given combination of the factors of production. There may be constant, increasing, or decreasing returns to scale if the output changes are the same, greater than, or less than, the proportional change of inputs, respectively.[13/] It should be noted that these proportional changes reflect a homogenous production function. On the other hand, economists frequently refer to "return to scale" and are intending to imply something about the more general concept of "return to size" or to a change in scale. This more general concept refers to situations in which all inputs are varied but in different proportions. The case of proportional changes refers to neutral effects on the combination of inputs, while the case of differing proportions refers to nonneutral effects on the production function. Regardless, a single unit isoquant is an inappropriate means of specifying the function.

[13/] This explanation of economies and diseconomies of scale concur to Jacob Viner's, "net economies and diseconomies of large scale production" (1952).

The case of neutral effects is shown in Figure 2.5, which uses the already familiar unit isoquant in specifying the function in input space. Considering a set of firms which are determined to be technically efficient, but all of differing scales, the most efficient unit isoquant would represent the largest firms, if economies of scale existed and the smallest firms, if diseconomies of scale existed. That is, if input per unit of output increases as the scale of activity increases from (a) to (c) and decreases with a further increase in scale to size (d), the unit isoquants representing each size firm could be labeled in exactly the same order as those in Figure 2.5.

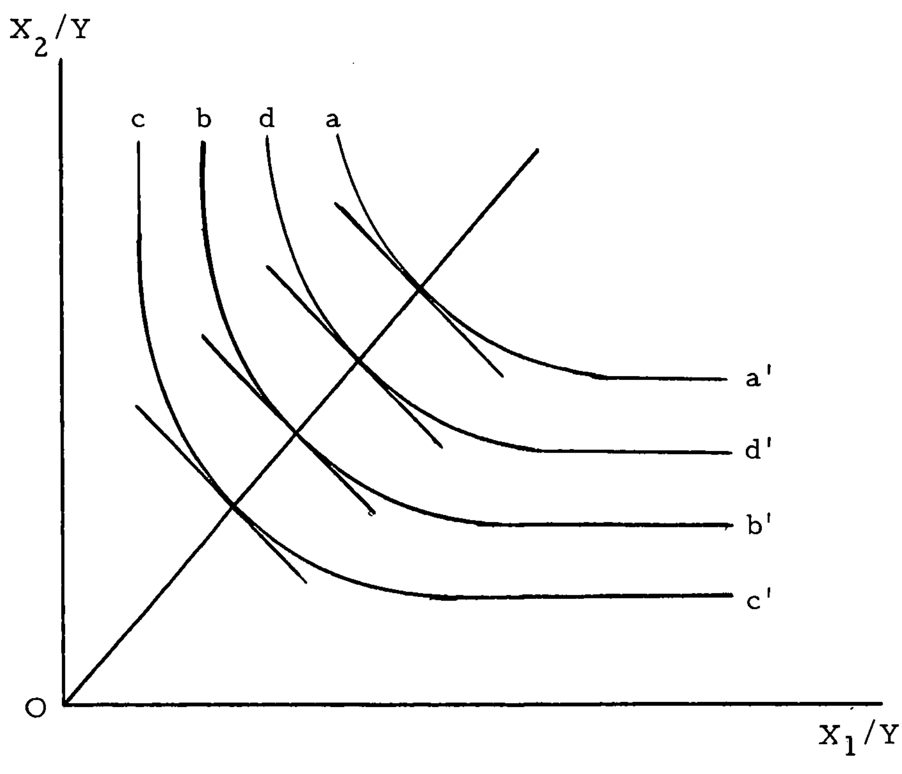

Figure 2.5. The case of neutral economies of scale.

Nonneutrality is much more common. That is, economies of scale are not "neutral" to factor proportions, and changes in size will usually involve both changes in input proportions and changes in inputs per unit of output. The always familiar example is the case of management. Seldom does management change in the same proportion as capital and labor.

Seitz illustrates a special case of nonneutrality, which is shown diagrammatically in Figure 2. 6.

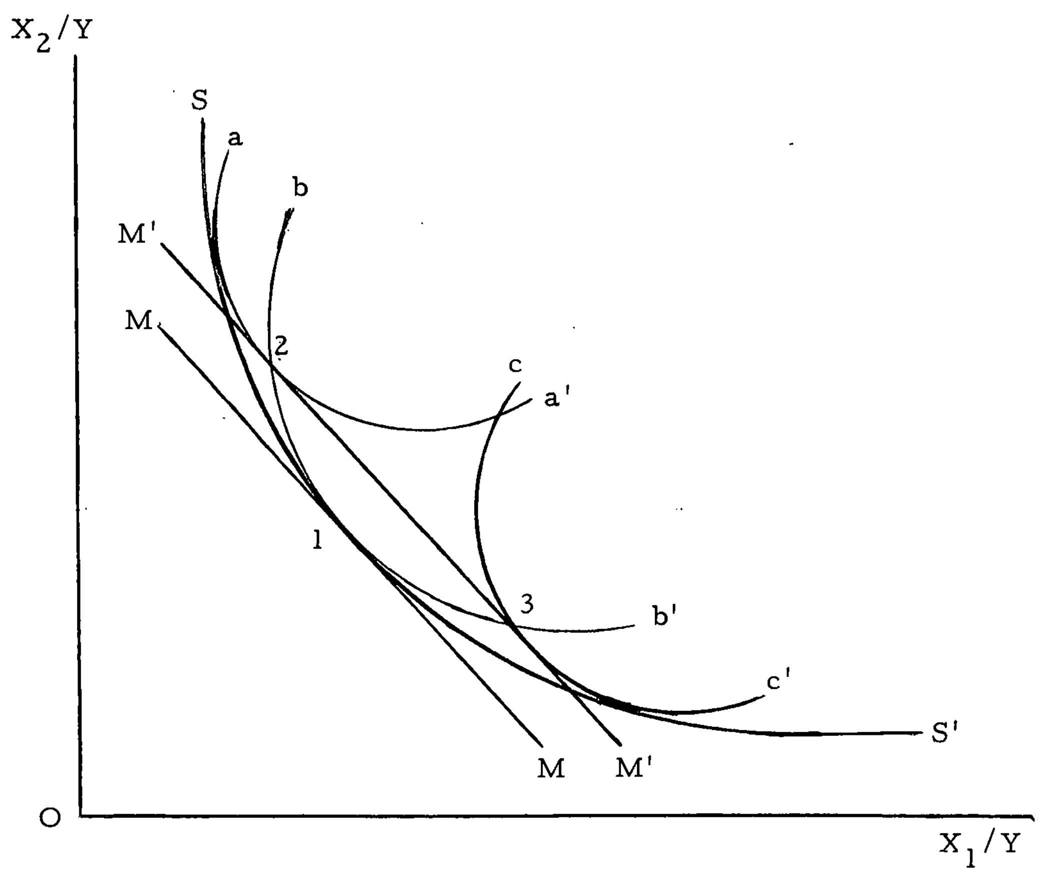

Figure 2. 6. Efficient unit isoquants for firms of various sizes: The case of nonneutrality.

> The curves aa', bb' and cc' represent the efficient unit isoquants from small, intermediate, and large scale activities, respectively. The curve SS' envelopes the unit isoquants for activities of various scales. If an isocost line is drawn tangent to SS' and the efficient unit isoquant of any scale activity, parallel isocost lines will be tangent to the efficient unit isoquants from all other scales of activities at points where the isoquants cross the isoquant of the activity used in defining the slope of the isocost lines. Thus, an activity of any size utilizing the optimum combination of the factors of production (for that size) would fall on the efficient unit isoquant of the plant operating at the optimum scale. In this sense, comparing the unit factor utilization data of the nonoptimum scale activities to the optimum scale activity would indicate that each is technically efficient but inefficient in the price dimension. Thus the expansion path in this case would exactly duplicate the efficient unit isoquant of the optimum scale activity given constant factor prices. The curve SS' is the locus of cost minimizing points which would be realized under varying factor prices by activities of varying scales (Seitz, 1970, p. 507).

This discussion by Seitz shows the need for a different measurement technique to handle economies of scale in the nonneutral case. If the same measurement techniques, used in the constant returns to scale case were applied to firms represented by the nonneutral production function, SS' could be estimated as the efficient unit isoquant over the observed range of factor combinations. Points representing efficient nonoptimum sized plants would then be rated as technically inefficient. The problem then arises that the size of operation preclude these firms from attaining the level of efficiency of the point which has been used to rate them.

What is needed is a method of analysis which will result in the selection of the true efficient points at all sizes of operation and give accurate measures for all of the remaining points. Farrell and Fieldhouse (1962) propose a method of considering variations in the production function over scale. This is shown in Figure 2.7, where the scale dimension is added and the production function can be specified in terms of a surface globally convex to the scale axis. A trace of the efficient unit isosurface (EUIS) at size S_2 is equivalent to the efficient unit isoquant (EUI) in the constant cost case. The trace E_1 to E_4 is an estimate of the expansion path for this productive process, and is given by tangencies of isocost lines and the EUIS at varying sizes. The actual computation of technical efficiency of a firm, given its size of operation (TES), in terms of the EUIS is strictly analogous to the constant cost case. The same holds for the price efficiency (PES) and economic efficiency (EES), given the particular size of the firm. For example, in Figure 2.7, TES is determined by the distance from the scale line at S_2 to point a divided by the distance from the scale line at S_2 to point b. The measures of PES and EES are similarly calculated as in the constant returns to scale case.

Given the TES, PES, and EES for each firm in the sample, the relative efficiency of alternative sizes of operation can be determined. That is, if a firm is operated efficiently at a nonoptimum size, it must be less efficient than a firm operated efficiently at the optimum size. In order to ascertain the degree of inefficiency associated with any size of firm, a sub-sample, those firms rated 100 percent EES, are selected

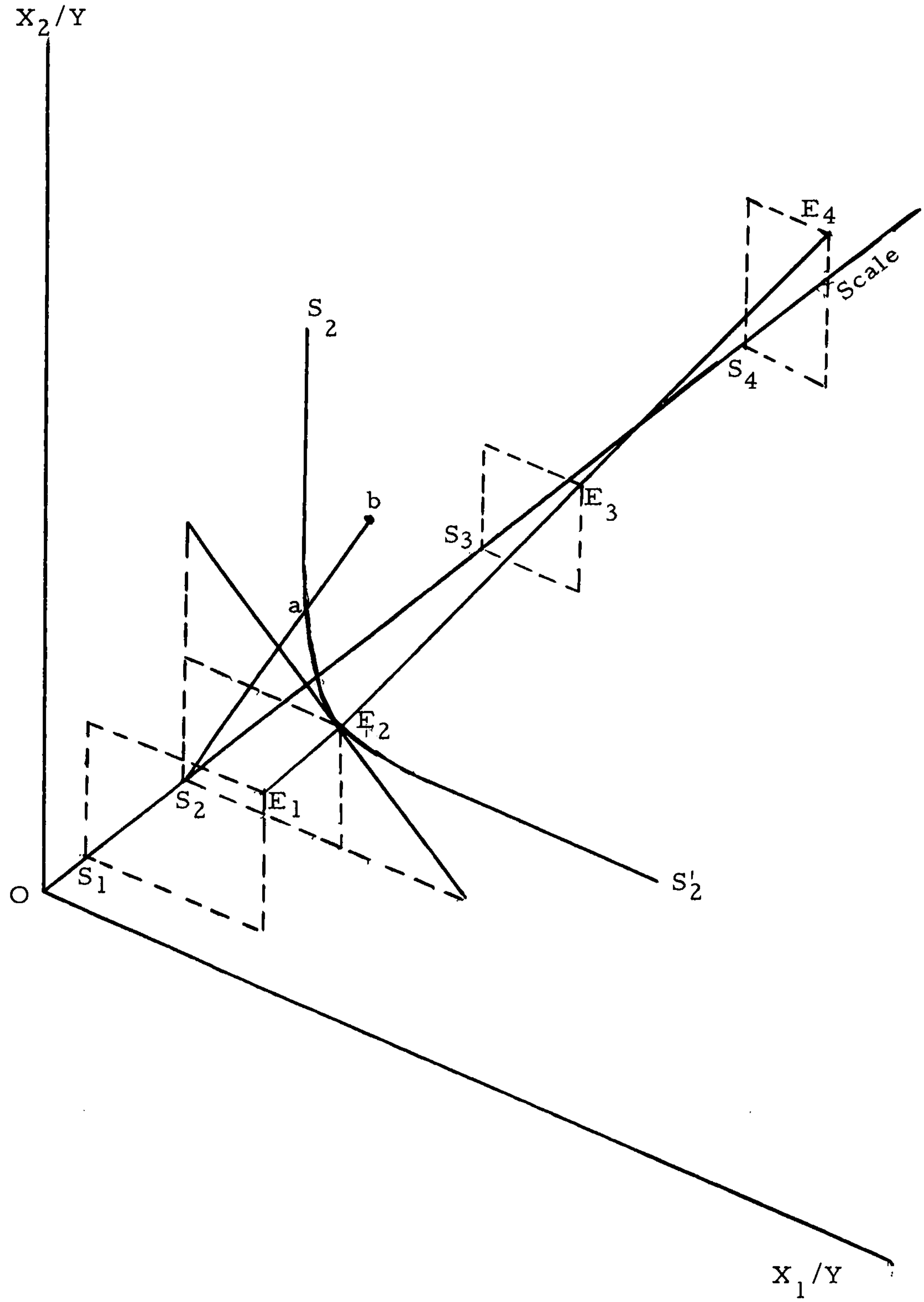

Figure 2.7. Measures of efficiency given scale.

and analyzed. This would be firms for which TES, PES, and EES = 1, such as E_1 through E_4 in Figure 2.7. The scale dimension would be excluded. The computational technique used in the constant cost over scale case is utilized to determine the relative levels of technical, pricing and economic efficiency associated with the operation of efficient firms of alternative sizes. These measures are termed technical scale efficiency (TSE), price scale efficiency (PSE), and economic scale efficiency (ESE). Estimates of the level of ESE for the remaining observations, not in the subsample, are derived by taking a weighted average of the ESE ratings of the observations in the subsample which are immediately larger and smaller. The product of EES and ESE is a measure of the overall economic efficiency of each firm (EE).

TSE measures the relative efficiency of different scale activities due to the physical nature of the production function. PSE is a measure of the degree to which optimal factor proportions vary as scale changes, and is a function of the curvature of the isoquants and the difference between the factor proportion ray and the expansion path. A homogenous production function, or any other production function with straight line expansion paths through the origin, will have a PSE of one and ESE will be invariant with respect to prices.

Bressler (1967) makes these efficiency measures more meaningful by showing the efficiency indices in relation to the long-run average cost curve. This relationship is shown in Figure 2.8, where an index of economic efficiency and an index of average cost are plotted in relation to scale. The bottom section of the figure has economic efficiency plotted relative to scale, where all firms on line LL' are technically efficient, but point e is the only point 100 percent efficient in the economic sense.

Economic efficiency is equivalent to the inverse ratio of average cost where the lowest average cost at given prices represents an index of 100 percent. This is shown in the upper section of Figure 2.8, represented as line GG'. It is of little surprise that the point representing firm e, has the highest index of economic efficiency and the lowest index of unit cost.

Another point can be made by the use of the bottom section of Figure 2.8. The economic efficiency indices can be shown in relation to scale to emphasize the separate contributions of scale, factor proportions, and price. For example, point M is of a scale represented by Og. The economic efficiency EE of point M is shown by the ratio gM/gk. But the best observed point at this size is point h, with economic efficiency well below 100 percent. However, we can separate the economic efficiency (EE) into the economic efficiency given this particular scale (EES), represented by gM/gh, and economic scale efficiency (ESE), represented by gh/gk. As stated previously EE is equal to EES times ESE.

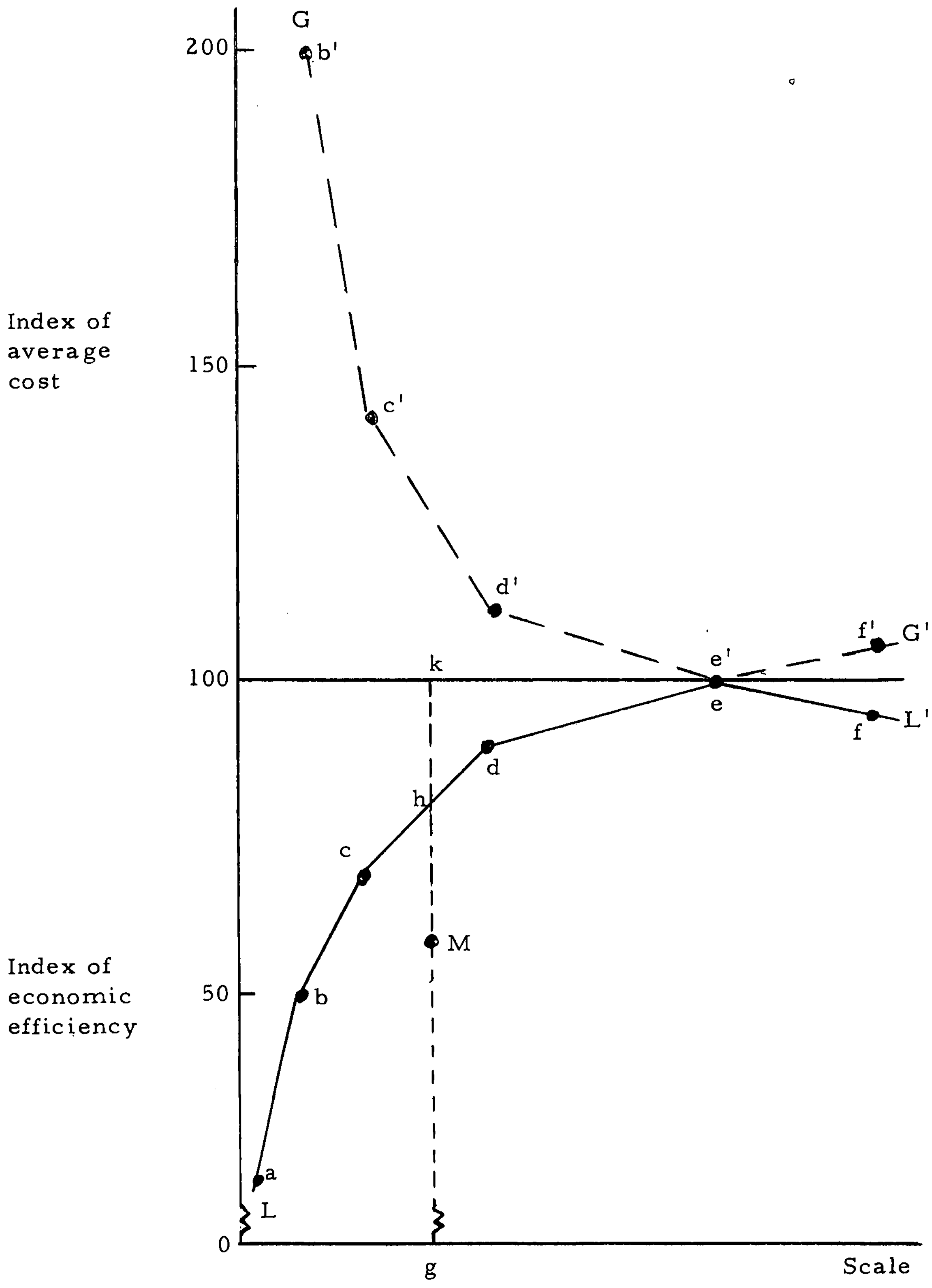

Figure 2. 8. The relationship of economic efficiency and average cost.

However, the indiscriminate use of the Farrell and Filedhouse method of dealing with scale, could lead to the wrong conclusions. That is, the assumption of global convexity[14/] and therefore convexity over scale may not be a reasonable assumption for all production functions. A lumpy input may generate several areas of local concavity. Failure to satisfy the assumption of convexity over scale can be discovered by examining the distribution of TES over scale. For example, if TES is high for only large and small scales, diseconomies followed by economies of scale exist.[15/]

Efficiency Defined Again--Mathematically[16/]

The measures of technical, pricing and economic efficiency have

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[14/] [This assumption] ". . . eliminates the possibility of diseconomies followed by economies of scale. Production theory indicates this assumption is reasonable. Given a set of production activities using similar inputs to produce a homogenous output, either constant returns or decreasing followed (by constant) by increasing returns would be expected. That is given the level of performance observed at two levels of operation, it is reasonable to expect that the technical knowledge exists to operate any intermediate scale activity at least as efficient as suggested by a linear combination of the observed activities" (Seitz, 1970, p. 509).

[15/] Seitz discusses an estimation procedure that generates estimates of TES, PES and EES, when the assumption of convexity is not met. The extimate is an approximation of the convex estimate but is not necessarily unique (1970, p. 510).

[16/] This general procedure was suggested by Peter V. Garrod in a working paper (1973).

been defined verbally and geometrically above. The purpose of this section is to present the mathematically equivalent definition of each of these measures of efficiency.

Economic efficiency was defined as the index of the average cost of the most efficient point on the production surface to the average cost of the firm for which the efficiency is being measured. That is economic efficiency (EE) is

$$EE_i = AC_E / AC_i$$

where

E = efficient point

$i = 1, 2, \ldots, n$

and

$$AC_E = P_1 X_{1E} + P_2 X_{2E}$$

$$AC_i = P_1 X_{1i} + P_2 X_{2i}$$

where

P_1, P_2 = prices of the inputs, X_1 and X_2

X_1, X_2 = quantities of inputs used per unit of output.

The input bundle (X_{1E}, X_{2E}) for the most efficient firm must meet two conditions: (1) $1 - f(X_{1E}, X_{2E}) = 0$, where f describes the efficient production surface, and (2) $MRTS_{(X_{2E}, X_{1E})} = P_1/P_2$, where MRTS is the marginal rate of technical substitution between

X_{2E} and X_{1E}.

Three additional definitions will also be helpful. First, $\gamma_E = X_{1E}/X_{2E}$ and $\gamma_i = X_{1i}/X_{2i}$, where γ is the slope of the input factor proportion ray. Second, dAC is defined as the difference between AC_E and AC_i due to the nonfulfillment of condition 2 above, meeting the equilibrium restrictions, while maintaining condition 1, being on the production surface. Lastly, ΔAC can be defined as the difference in average cost due to the nonfulfillment of condition 1, given γ_i, the factor proportion associated with firm i. Given these definitions, the following relationship exists;

$$AC_i - AC_E = dAC + \Delta AC .$$

From this relationship follows the definitions of price and technical efficiency, where

$$PE_i = \frac{AC_E}{AC_E + dAC}$$

and

$$TE_i = \frac{AC_E + dAC}{AC_i} = \frac{AC_E + dAC}{AC_E + dAC + \Delta AC} .$$

Frontier or Average Functions

The measures of efficiency presented thus far have been based on the comparison of actual observations to an estimation of the frontier production function. Some attributes of the frontier model may lead to biased results. The problem of biased estimates of technical efficiency due to the inability of the linear model to differentiate various levels of the same input in certain cones has been discussed above. The problems associated with estimating the efficiency indices when the assumption of global convexity is inappropriate for a production function has also been discussed above.

In addition to these two previous operational difficulties, the data problem associated with the estimation may be severe. Although the frontier function corresponds closely to the theoretical ideal, the frontier is determined by the extreme observations in the data set. Thus, the estimation of the frontier is strongly sensitive to errors of sample observations. Aigner and Chu argue that such estimation must be biased in every dimension of the production space, analogous to the sample maximum as an estimator of a population maximum (1968, p. 827).

Two biases arise, one optomistic, the other pessimistic. The existence of sampling bias to any degree would make the efficiency estimates optimistic and estimates of the efficiency would over-estimate the true relative efficiency of the firms. The other source of bias arises from the inherent stochasticity of the data and the deterministic nature of the frontier function defined by linear programming techniques. A large sample cannot contract the frontier, but it can enlarge it. Thus the sample may bias the efficiency indices in a pessimistic manner. The two biases will tend to offset one another, but the extent to which either is dominant is unknown.

In general, the estimation potential of the frontier model is reduced by a lack of available statistical inference procedures for discriminating between function specific models, and among variables. An alternative may be the use of an average estimation of the production function.

Average production functions can be defined as those estimated by a statistical technique such as least squares which minimizes the sum of the squares of the errors, over the sample. Least squares has dominated economics, mainly because it is based on a statistical theory that is well accepted and now well engrained in the discipline. However, the properties of an estimation procedure in defining an average production function is not the issue at the present time. The more relevant question is, how appropriate is an average model in defining efficiency.

Timmer (1970) discusses this question in an analytical manner which compares average and frontier functions relative to their statistical relationship, economic relationship, and their relative contribution in understanding technical efficiency and change.

The statistical relationship has been mentioned above. No formal statistical relationship can be made between an average production function fitted to a functional form such as the Cobb-Douglas and a frontier production function estimated by linear programming. There is no relationship because the frontier is drawn from a subset of points that are summarized by the average function. However, in an intuitive way, one might expect a high correlation between the ranking of indexes computed by the two methods.[17/]

On the other hand, the economic relationship between the two functions has undergone more debate than the statistical relationship. This debate was touched upon earlier, and boils down to the difference between average practice and best practice in an industry. The frontier production function represents the best techniques in practice.

The average production function has a less clear cut interpretation as discussed by Aigner and Chu.

> A group of economists did notice the obvious conflict with theory, however, and some rationalization of this position was attempted. What they did was to assume that the function to be estimated, i.e., the conceptual construct, is an "average" production function for the industry. Some firms could therefore produce more than the average; some,

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[17/] This is similar to M.G. Kendall's observation in discussing Farrell's original paper (Farrell, 1957, pp. 286-87).

> less. But the meaning of such an "average" function is not necessarily clear. Average in the sense of what? a conditional median? a mean? or, a mode? More importantly, average <u>about</u> what? about output? about some input? about technology? or about something else? Some economists refer to it as the function for a "firm of average size". This interpretation cannot be correct unless it is assumed that the parameters of the function are random variables and have their expectations equal to those of the firm of "average size". Others seem to refer to the average function as reflecting some sort of "average technology". But it would be infeasible to assume that a firm which possesses "average technology" with respect to capital also has an "average technology" with respect to labor (1968, p. 829-30).

This last criticism may not be sound. Timmer disagrees with Aigner and Chu on this last point and explains that

> Technology refers to the whole productive structure of the firm rather than only the labor input or only the capital input. Thus the frontier production function at any point in space relates amounts of all inputs to output--in fact, to maximum output attainable from that <u>particular</u> combination of inputs. There may be a dozen firms with approximately the same input combination, but only one or two achieve maximum output from those inputs. The other firms achieve less, and it is meaningful to speak of the average attained output for that particular combination of inputs, and for that output to be representative of "average technology". The distinction between "average" and "best" can be justified if the comparison is between production functions and not between differential efficiency in the use of single productive factors (1970, p. 125).

In addition, Timmer gives some examples of the usefulness of comparing frontier and average functions in estimating technological change. However, most of the examples contain the dimension of time, which is not considered in this study. If the average function is a neutral transformation of the frontier, at any point in time, then the two models may have some comparative value, in that the parameters of the average function give additional information which is not available from a frontier estimation. However, the problems associated with misspecification of the estimated average function seem to outweigh the merits of any useful information that may be gained. Therefore, a direct average estimation of a production function will not be made in this study.

An Alternative Approach

One group of economists, Youtopoulos, Lau and Somel (1970), in searching for an appropriate measure of efficiency, submit that the production function is the wrong trap for the purpose of capturing relative efficiency. They summarize this argument around the rigid assumptions that are implicit in the estimation of production functions.

> It is well known that all firms would have the same quantities of inputs and outputs (and as a result only one point on the production surface would be observable) if:
>
> (1) All firms had the same production function, i.e., the same technical knowledge and identical fixed factors;
>
> (2) All firms faced the same prices in the product and factor markets; and
>
> (3) All firms maximized profits perfectly and instantaneously.
>
> Nevertheless we observe in the world firms that produce (roughly) homogenous output having different factor

> intensities and varying average factor productivities. It is, of course, sufficient to explain the world if we assume that firms behave randomly. They are ignorant of their production, cost, and return functions and, no matter what prices they have to take as given, they do not behave as if they maximized profits. If this is the case, any attempt to measure relative economic efficiency could as well be abandoned.
>
> On the other hand, suppose we establish that firms behave according to a certain decision rule which we can conveniently call profit maximization with respect to a set of exogenous variables, such as prices and fixed factor of production. Then the observed interfirm differences in factor intensities and productivities still need explaining. The two possible explanations are that (1) firms use different input mixes because they face different prices; and/or (2) firms use different input mixes because they have different endowments of fixed factors of production, i.e., they have neutral differences in technical efficiency (Yotopoulos, Lau, and Somel, 1970, p. 54).

Therefore, these economists concluded that a test of relative economic efficiency should include two parts. First, given different factor prices and quantities of fixed factors of production, the test should determine if firms behave according to a decision rule such as profit maximization.

Second, if and only if a decision rule appears to be generally applicable to all firms in the industry under study, then the question arises whether a set of firms is relatively more economically efficient than another because it is more successful in responding to the set of prices it faces (price efficiency) and/or because it has higher quantities of fixed factors of production, including management (technical efficiency). Wise and Yotopoulos (1969) discuss the theoretical aspects and offer a general test of the first part, establishing a measure of economic rationality, such as profit maximization. Lau (1971) and Yotopoulos (1973) offer an estimation procedure for the second test, determining relative efficiency.

The theoretical basis of the Wise-Yotopoulos test will be reviewed below, but will not be estimated in this study. Assuming that retail meat operations attempt to follow the profit maximizing rule, the Lau and Yotopoulos model is used to estimate relative efficiency between groups of retail stores.

A Brief Review of Economic Rationality[18/]

A large amount of economic theory assumes that firms have knowledge of their production, cost, and return functions, which implies certain economic rationality relating to the profit maximization conditions. The hypothesis of economic rationality has been defended on the basis of *a priori* theoretical considerations, and supported by some empirical observations. The hypothesis has been challenged on the deductive reasoning and casual empiricism. Two of the participants in the debate have been Milton Friedman (1968) and Herbert Simon (1959). The general validity of profit maximization has been supported by Milton Friedman on the basis of two kinds of

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[18/] This section is basically a review of Wise and Yotopoulos (1969).

indirect evidence: First, there is evidence of the "billiard-player hypothesis" type; that is, one does not have to be an expert in billiard-ballistics in order to be an expert billiard player.

> Unless the behavior of business men is some way or other approximated behavior consistent with the maximization of returns, it seems unlikely that they would remain in business for long (Friedman, 1968, p. 35).

Second, there is evidence arising from failure of the implications of the hypothesis to be contradicted in countless applications:

> The evidence for a hypothesis always consists of its repeated failure to be contradicted, continues to accumulate as long as the hypothesis is used, and by its very failure is difficult to document at all comprehensively. It tends to become part of the tradition and folklore of a science revealed in the tenacity with which hypotheses are held rather than in any textbook list of instances in which the hypothesis has failed to be contradicted (Friedman, 1968, p. 35).

However, the hypothesis of profit maximization and the theory of the firm, which is built on this hypothesis, has been challenged by some behavioral scientists. One of those attacks is Simon's "satisficing behavior" theory, which introduces into economics the notion of satiation that enters motivation in psychology. Rather than allocating resources to attain profit maximization, the firm may behave in a manner that admits an optimum set of "viable" solutions which are consistent with the survival of the firm:

> In most psychological theories the motive to act stems from drives and action terminates when the drive is satisfied. Moreover, the conditions for satisfying a drive are not necessarily fixed, but may be specified by an aspiration

> level that itself adjusts upward or downward on the basis of experience. . . . If we seek to explain business behavior in the terms of this theory we must expect the firm's goal to be not maximizing profit but attaining a certain level or rate of profit, holding a certain share of the market or a certain level of sales (Simon, 1959, p. 263).

Wise and Yotopoulos set forth a procedure for testing for profit maximization, which is interesting in its own right, but will not be pursued in this study. However, the assumption that each retail meat firm follows the rules of profit maximization will be made in using the following profit function model devised by Lau and Yotopoulos.

This assumption seems reasonable since most of the firms in each market area are relatively small and sell a rather homogenous, nondifferentiated product. In addition, information about prices charged by each firm is readily available.

A Profit Model[19]

Measurement of Relative Efficiency

Lau and Yotopoulos (1971) review the conceptual and empirical approaches of measuring relative efficiency, and based upon the deficiencies of the existing approaches, set out on their own to classify economic, price and technical efficiency. In doing so, they

[19] This section is summarized from Lau and Yotopoulos (1971, p. 94-109).

set up some minimum requirements that the relative economic efficiency measure should meet:

> (i) It should account for firms that produce different quantities of output from a given set of measured inputs of production. This is the component of differences in technical efficiency. (ii) It should take into account that different firms succeed to varying degrees in maximizing profits, i.e., in equating the value of the marginal product of each variable factor of production to its price. This is the component of price efficiency. (iii) The test should take into account that firms operate at different sets of market prices. The decision rule on profit maximization yields actual profits (as well as quantity of output supplied and quantities of variable inputs demanded) as a function, *inter alia*, of input prices. It is clear that two firms of equal technical efficiency which have successfully maximized profits would still have different values of profits as long as they face different prices (Lau and Yotopoulos, 1971, p. 95).

The measurement of technical, pricing and economic efficiency can be seen in a general manner in the following example. Consider two firms with the same production functions

$$V^1 = A^1 F(X^1) ; \qquad V^2 = A^2 F(X^2) ,$$

where:

V^i = output

A^i = the technical efficiency parameter

X^i = vector of inputs

and i denotes the specific firm.

Given exactly the same quantities of each of the inputs used in the production of V, a firm is more technically efficient if it produces a larger output. That is, if A^1 is greater than A^2, firm 1 is more technically efficient than firm 2. Given a specific functional form for the production functions, a relevant test of technical efficiency will be the null hypothesis that A^i remains constant across all firms.

By definition, a firm is price efficient if it maximized profits. However, Lau and Yotopoulos point out two complications in connection with that definition of price efficiency. First, if the price of the inputs are different for each firm, the firms will equate the value of the marginal product of each factor to its firm-specific opportunity costs. Second, firms may not maximize profit, thus the marginal conditions do not hold. Therefore, the firm may equate the marginal value product of each factor to a constant proportion of the respective firm specific factor prices (1971, p. 95-96). For the two firms, the marginal conditions are

$$p \frac{\partial V^1}{\partial X_j^1} = k_j^1 c_j^1 \; ; \qquad p \frac{\partial V^2}{\partial X_j^2} = k_j^2 c_j^2$$

where

$k_j^i \geqq 0$ and

i = firm subscript

j = input subscript.

The firm and input specific k_j^i's are indexes of the decision rule that describes the firms profit maximizing behavior.[20] If $k_j^i = 1$, the firm is maximizing profit with respect to that particular input. If and only if, two firms have equal pricing efficiency with respect to all variable inputs, will $k_j^1 = k_j^2$, $j = 1, \ldots, m$. Therefore, relative pricing efficiency can be tested by testing the null hypothesis that $k_j^1 = k_j^2$. In addition, each firm can be tested with respect to each variable input, to see if absolute pricing of the input is according to the profit maximization rule. That is, the null hypothesis, $k_j^i = 1$, can be used with regard to each variable factor for each firm.

Economic efficiency is a function of both technical and pricing efficiency, and for firms of different technical and price efficiency,

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[20] In our formulation, the k's reflect a general systematic rule of behavior--a decision rule that gives the profit-maximizing marginal productivity conditions as a special case. That decision rule for the firm consists of equating the marginal product to a constant times the normalized price of each input may be rationalized as follows: i) consistent over-or under-valuation of opportunity costs of the resources by the firm; ii) satisficing behavior; iii) divergence of expected and actual normalized prices; iv) divergence of the subjective probability distribution of the normalized prices from the objective distribution of normalized prices; v) the elements of k^i may be interpreted as the first-order conditions of a Taylor's series expansion of arbitrary decision rules of the type

$$\frac{\partial F}{\partial X_j^i} = f_j^i(c_j^i), \quad i = \text{firms}, \quad j = \text{variable inputs}$$

where $f_j^i(0) = 0$ and $f_j^{i'}(c_j^i) \geq 0$ (Lau and Yotopoulos, 1971, p. 99).

but identical prices, the firm with the greatest profits is the most relative economic efficient firm. This simply implies that a relevant test of equal economic efficiency between firms, is the joint test of the null hypotheses, $A_1 = A_2$ and $k_j^1 = k_j^2$.

The Profit Function

In a pioneering effort, McFadden (1972) extended the concept of cost functions to revenue functions and profit functions and proved the McFadden Duality Theorem--the profit function analog of the Shephard (1953)-Uzasa (1964) Duality Theorem on cost and production functions.

The results of his work can be seen by considering a firm with a production function with the usual neoclassical properties[21/]

$$V = F(X_1, \ldots, X_m; Z_1, \ldots, Z_n) \qquad (2.1)$$

[21/] Lau (1972) states these assumptions with regard to the production function:

a) The production function is continuous in X and Z; twice differentiable in X and once differentiable in Z.

b) The production function is strictly increasing in X and Z.

c) The production function is strictly concave in X in the non-negative orthant.

d) F is finite for all finite X and Z. F is unbounded as X and Z approach infinity.

where V is output, X_i represents variable inputs and Z_i represents fixed inputs of production. The profit function is defined as total revenue less total variable costs, and can be written as

$$P' = pF(X_1, \ldots, X_m; Z_1, \ldots, Z_n) - \sum_{i=1}^{m} c_i' X_i \qquad (2.2)$$

where P' is profit, p is the unit price of the output, and c_i' is the unit price of the variable input.

Assume that a firm maximizes profits given the level of its fixed inputs. The marginal productivity conditions for such a firm are

$$p \frac{\partial F(X;Z)}{\partial X_i} = c_i', \quad i = 1, \ldots, m. \qquad (2.3)$$

By normalizing the price of the ith input, defining $c_i = c_i'/p$, Equation 2.3 can be rewritten as

$$\frac{\partial F}{\partial X_i} = c_i, \quad i = 1, \ldots, m. \qquad (2.4)$$

By similar deflation, Lau and Yotopoulos rewrite 2.2 as 2.5, where P is defined as the "Unit-Output-Price" profit, or UOP profit

$$P = \frac{P'}{p} = F(X_1, \ldots, X_m; Z_1, \ldots, Z_n) - \sum_{i=1}^{m} c_i X_i . \qquad (2.5)$$

Equation 2.4 can be solved for optimal quantities of variable inputs, X_i^*'s, as functions of the normalized prices of the variable inputs and the quantities of the fixed inputs.

$$X_i^* = f_i(c, Z) \qquad i = 1, \ldots, m. \tag{2.6}$$

By substitution of (2.6) into (2.2), the actual profit function is obtained

$$\pi_A = p[F(X_1^*, \ldots, X_m^*; Z_1, \ldots, Z_n) - \sum_{i=1}^{m} c_i X_i^*] \tag{2.7}$$

and

$$\pi_A = G(p, c_1', \ldots, c_m'; Z_1, \ldots, Z_n).$$

This can be rewritten as

$$\pi_A = pG^*(c_1, \ldots, c_m; Z_1, \ldots, Z_n) \tag{2.8}$$

The UOP profit function is therefore given by

$$\pi^* = \frac{\pi_A}{p} = G^*(c_1, \ldots, c_m; Z_1, \ldots, Z_n). \tag{2.9}$$

Lau and Yotopoulos then point out that maximization of profit in (2.2) is equivalent to maximization of UOP profit in (2.5) in that they yield identical values for the optimal X_i^*'s. Hence π^* in (2.9) indeed gives the maximum value of UOP profit in (2.5).

Lau (1972) provides all of the theorems that point out that the UOP profit function is decreasing and convex in the normalized prices of variable inputs and increasing in quantities of fixed inputs. It also follows that the UOP profit function is increasing in the price of the output.

A set of dual transformation relationships connect the production function and the profit function. Lau's (1972) schematic summary of these relationships is shown in Table 2.1.

The merits of an average function have been discussed above. Lau and Yotopoulos move the discussion to the more specific, and emphasize the advantages of working with the UOP profit function instead of the traditional production function.

> First, the Shephard-Uzawa-McFadden Lemma allows us to derive the firm's supply function,[22/] V^*, and the firms factor demand functions, X_i^*'s, directly from the UOP profit function (2.9) instead of solving Equation (2.4) which involves the production function. Second, it is clear that supply function and factor demand functions may be obtained by simply starting with an arbitrary UOP profit function which is decreasing and convex in the normalized prices of the variable inputs and increasing in the fixed inputs. In addition, by duality, as McFadden has shown, there exists a one-to-one correspondence between the set

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[22/] This supply function can be written as

$$V^* = \pi^*(c, Z) - \sum_{i=1}^{m} \frac{\partial \pi^*(c, Z)}{\partial c_i} c_i \; .$$

Table 2.1. Schematic summary of the transformation which connects the production and UOP profit functions.

	Primal	Dual
Function:	Production-Function	UOP profit function
Variables:	Quantities: X_i	Normalized Prices: c_i
Passive variables:	Fixed Inputs: Z_j	Fixed Inputs: Z_j

Transformation

	Primal	Dual
1.	$P^* = F(X_1, \ldots, X_m, Z_1, \ldots, Z_n) - \sum_{i=1}^{m} c_i X_i$	$\pi^*(c_1, \ldots, c_m, Z_1, \ldots, Z_n)$
2.	$\frac{\partial F}{\partial X_i} = c_i$	$c_i = \frac{\partial f}{\partial X_i}$
3.	$X_i = -\frac{\partial \pi^*}{\partial c_i}$	$\frac{\partial \pi^*}{\partial c_i} = -X_i$
4.	$\frac{\partial F}{\partial Z_i} = \frac{\partial \pi^*}{\partial Z_i}$	$\frac{\partial \pi^*}{\partial Z_i} = \frac{\partial F}{\partial Z_i}$
5.	$F = \pi^* - \sum_{i=1}^{m} \frac{\partial \pi^*}{\partial c_i} c_i$	$\pi^* = F - \sum_{i=1}^{m} \frac{\partial F}{\partial X_i} X_i$
6.	Z_i	Z_i

Source: (Lau, 1972).

> of convex profit functions. Every concave production function has a dual which is a convex profit function, and vice versa. Hence, without loss of generality, one can consider for profit-maximizing, price-taking firms, only profit functions in the analysis of their behavior without an explicit specification of the corresponding production function. This provides a great deal of flexibility in empirical analysis. Third, by starting from a profit function, we are assured by duality that the resulting system of supply and factor demand functions is obtainable from the maximization of a concave production function subject to given fixed inputs and under competitive markets. Fourth, the profit function, the supply function, and the derived demand functions so obtained are functions only of the normalized input prices and the quantities of fixed inputs, variables that are normally considered to be determined independently of the firm's behavior. Econometrically, this implies that these variables are exogenous variables, and by estimating these functions we avoid the problem of simultaneous equation bias to the extent that it is present (1971, p. 98).

It is with these arguments in mind, that the UOP profit function is used in this study as an alternative procedure in estimating relative efficiency indices. In addition, some degree of comfort may be found in estimating relative efficiency with a method that is usually considered more applicable to describing a stochastic universe, such as least squares. The frontier is a beckoning challenge, but given nothing with which to compare the results, the adventure may be an empty vacuum.

Frontier and Profit Functions

In an earlier section, a comparison was made between frontier and average functions. At that time the advantages and disadvantages of both methods of estimation were presented. As a result, the positive and negative attributes of the frontier model, which is being compared to the profit model in this section, will not be presented here. However, the reader should note that the statistical discussion, relative to the average and frontier functions, is applicable to this analysis, but, the theoretical issues are not pertinent to this section. That is, the profit model is estimated by single equation least squares, and thus the comparative statistical advantages and disadvantages previously discussed with respect to the average and frontier functions apply here.

The important theoretical aspect of the frontier and profit approaches is that both estimate a production function, which in turn serves as the basis for testing hypotheses concerning relative economic efficiency. The differences in the theoretical premises which underlie each of these procedures must not be ignored when interpreting results. That is, the theoretical bases of the frontier and the profit models are different, and as a result, may not yield the same conclusions concerning what may appear to be an identical hypothesis test of relative efficiency.

The question then, is, how do relative economic, pricing and technical efficiencies differ as determined by the two models? A search for the answer to this question can take many directions, but the one which will be followed here is to define each term for both models, and to review how each measure is determined. Hopefully, the more obvious and intuitive differences will be revealed.

Economic efficiency is defined in the frontier model as an index of the average costs of the firm in the survey. That is, economic efficiency is the ratio of the average cost of the most efficient firm, given a specific scale, to the actual average cost of the firm for which the efficiency measure is being determined. However, relative economic efficiency is the quantitative measurement of interest. Relative measures can only be made when more than one firm or group of firms exist. In this study, relative economic efficiency determined by the frontier model refers to the comparison of the economic efficiency of two groups of firms: those that utilize the carcass system and those that use the fabricated system of handling beef. Therefore, a measure of economic efficiency for each group must be calculated and then a relative comparison between groups can be made.

The economic efficiency of each group as a whole is determined by taking the economic efficiency of each firm in the group, as defined above, and determining the simple average. The measure of equal relative economic efficiency then becomes a test of the hypothesis that the mean values for each group are not statistically different from each other.

On the other hand, relative economic efficiency between the two groups of retail stores, as determined by the profit model, is defined as the difference between the estimated maximum UOP profit for each group. That is, each firm in the sample is classified into one of the groups under consideration. An estimated maximum profit is then determined for each of these groups. This assumes, by duality, that each profit function corresponds to a production function for the group, and that these production functions are the same up to a neutral efficiency parameter. The test of equal relative efficiency using this method becomes a test of the hypothesis that the maximum UOP profit for all groups are not statistically different.

At a glance, the hypothesis test for the two methods may appear to be the same. But the frontier method considers only cost, while the profit model considers cost and revenue. This may be made clearer by assuming a two input case and recalling that the least cost firm has combined its variable inputs so that $MP_1/MP_2 = P_1/P_2$. This represents one point on the long run average cost curve, and consequently one point on the expansion path. In addition, this point represents the firm which is most price efficient given a particular input price ratio. However, this does not necessarily represent an output which will maximize profits--the definition of price efficiency in the profit model. By expressing P_1/MP_1, as the change in cost for a change in output, one can see that this is the same definition as marginal cost, and $P_1/MP_1 = MC_Q$. The same holds true for the second variable input, and thus the relationship

$$\frac{MP_1}{P_1} = \frac{MP_2}{P_2} = \frac{1}{MC}$$

is true for the minimum cost firm used in calculating economic efficiency. This is a necessary, but not a sufficient condition for profit maximization. Assuming that the firm is in pure competition on the selling side, marginal revenue and the price of the output are equal. Therefore, for profit maximization, defined as MC = MR, equilibrium can be expressed as

$$\frac{MP_1}{P_1} = \frac{MP_2}{P_2} = \frac{1}{MC} = \frac{1}{MR} = \frac{1}{P_Q} .$$

It should also be noted, that maximum profit can not be estimated, unless a specific specification of the functional form of the production function is known. The estimates of maximum profit from the UOP profit model can be made without actually using the production function because of duality. But, this is not the case with the frontier method. Since no specific functional form is given to the frontier production function, the equalibrium level of inputs and output for profit maximization can not be determined.

A necessary assumption for measuring relative efficiency in both models is the restriction that the technical differences in the production functions are neutral. If this assumption is not made, each model must explicitly define changes in the output due to different input intensities and, or elasticities of substitution.[23/] Fortunately, the researcher may receive some warning when this assumption does not hold true. In the profit model, a test of the constancy of the coefficients associated with the variable inputs in each production function can be made. That is, if the assumption of technical neutrality does not hold between each group in the sample, the estimated coefficients for the variable inputs should be significantly different.

On the other hand, simply observing the technical efficiencies for each firm in each group, may provide the necessary information needed to decide if the neutrality assumption has been violated with

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[23/] In discussing technological change Brown defines elasticity of substitution as

$$\sigma = \frac{(K/L)d(K/L)}{(f_L/f_K)d(f_K/f_L)}$$

where f_L is the marginal product of labor and f_K is the marginal product of capital.

"The ratio of the marginal product of capital to the marginal product of labour is the marginal rate of substitution of labour for capital. . . the elasticity of substitution as defined in the formula relates the proportional change in the relative factor inputs to a proportional change in the marginal rate of substitution between labour and capital (or the proportional change in the relative factor price ratio). Intuitively, it can be thought of as a measure of the ease of substitution of labour for capital; it can also be conceived of as a measure of the 'similarity' of factors of production from a technological point of view" (1966, p. 18).

respect to the frontier model. This can be made clearer by using the four diagrams in Figure 2.9. Each diagram shows one of the situations that may exist, given a two input world. In panel A, a neutral change has altered the production functions and has not affected the marginal rate of substitution. That is, the marginal rate of substitution is the same at point a and b. In a like manner, panel B represents a nonneutral change in the production functions. Although $\alpha = \beta$, so that both firms represented by AA' and BB', respectively, face the same relative factor prices, $\alpha' > \beta'$ and thus firm BB' has a higher X_2/X_1 ratio. A researcher can gain valuable information about technological change using the frontier estimates and observing the plots of the frontier functions. Unfortunately, the value of the Farrell technique in this regard holds only in a two-factor world. With more than two factors it becomes almost essential to fit the frontier to some functional form, thus restricting the elasticity of substitution.

In the two remaining cases, the violation of the neutrality assumption is easier to identify, even when there are more than two inputs. It is evident from examining panel C, that firm AA' is technically more efficient at one set of factor prices and firm BB' is efficient at another set of factor price ratios. If they face different factor price ratios because of market conditions, it is possible for both technologies to exist side by side. In this case, when the

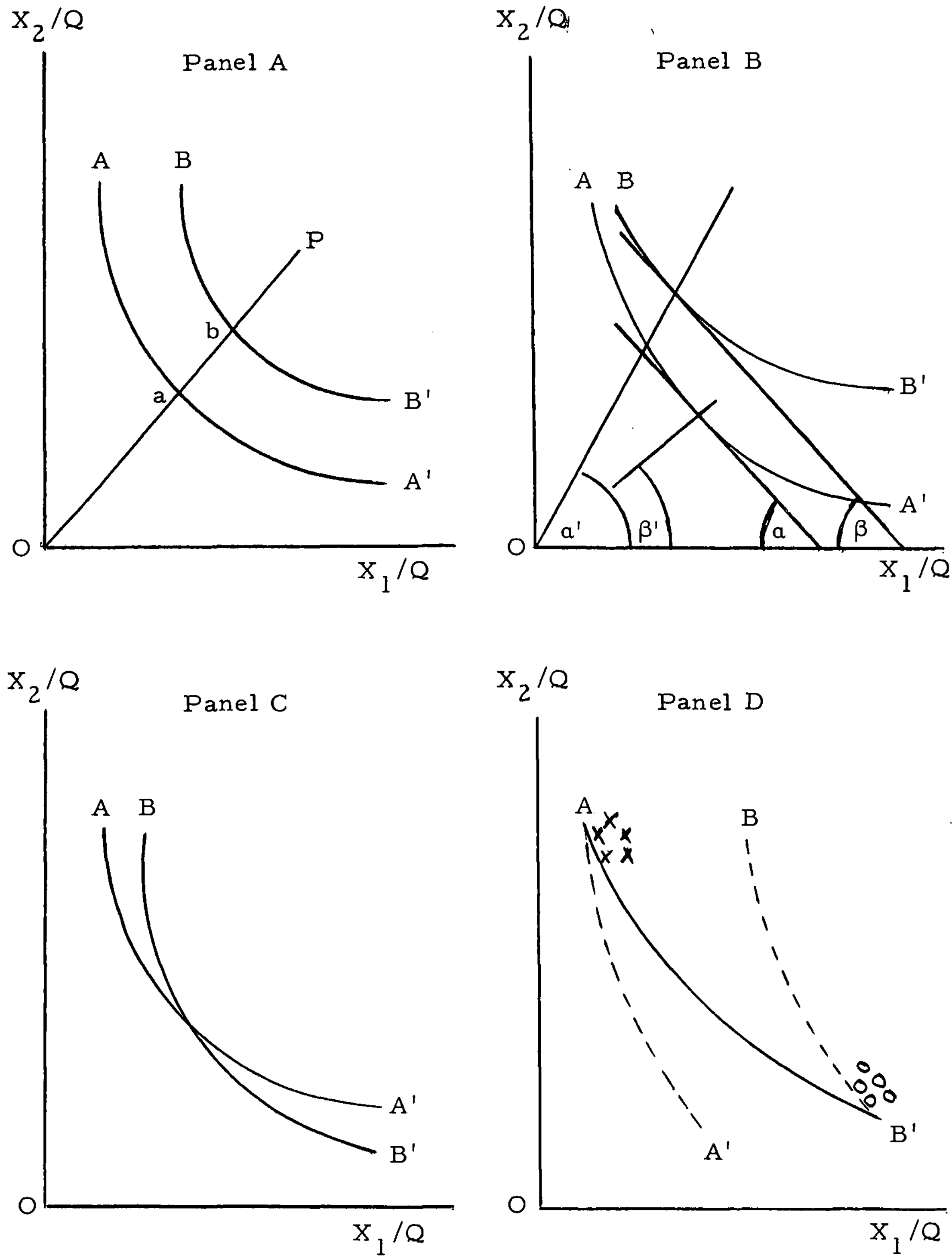

Figure 2.9. Four examples of possible effects of technological change.

production function is different for the two groups, the frontier measure is inconclusive in ascertaining a comparison of relative economic or technical efficiency. This situation will be obvious to the researcher if, in examining the technical efficiency indices, there are firms of both technologies on the production surface. That is, firms representative of each technology will have a technical efficiency of one.

This last observation could also be identifying the situation which is diagrammatically presented in panel D. If the data are grouped within a certain range which does not generally overlap, the linear programming technique may estimate a frontier which is common to both sets of data. That is, the problem of specification has arisen. As a result, the researcher may not be measuring the intended hypothesis. As previously mentioned, this could be the situation when firms representing each technology appear on the production surface. Therefore, the only useful measure of relative efficiency with respect to the frontier model, as defined in this study, is the case shown in panel A.

Summary of the Theoretical Framework

The theory used to measure technical, pricing and economic efficiency of alternative vertically coordinated retail meat systems is based on neoclassical production theory of the firm. But, of more interest to this study, the theory is applicable for all firms in the same industry. Therefore, differences between firms, due to a different technology employed and a different scale, can be analyzed with the aid of these theoretical concepts.

Two approaches to the theory have been discussed above, the frontier method and the profit function method. Each has its own advantages and disadvantages, both from the theoretical point of view and from the practical aspect of hypotheses testing. Both theoretical approaches are used in this study. The Farrell model gives an estimate of a frontier production function, while the Lau and Yotopoulos model is used to estimate the profit function.

In Chapter IV, each of the models will be used to test a set of hypotheses. The empirical estimates will be presented for each model. However, before the final models of the study are presented, the events leading to these models are of interest. Chapter III outlines the study area and the variables that were included in the survey. In addition, the progression from the survey model to the models that are used in the quantitative analysis of the study is presented.

III. DESCRIPTION OF THE STUDY PARAMETERS

Units of Observation

Introduction

The purpose of this chapter is to bridge the concepts discussed in the theoretical efficiency models with the specific research problem at hand, measuring the efficiency indices of alternative vertically coordinated retail meat distribution systems in the Pacific Northwest. As mentioned in the introductory chapter, this study focuses primarily on the differences in distribution systems which arise from differences in the handling of slaughtered beef.

The vertically coordinated systems of marketing slaughtered beef, from the packer to the retail level, are shown in Figure 3.1. All of the systems start with carcasses from a packing plant cooler, and end with packages of meat in a retail store. There are basically four systems in use in this intermediate distribution sector in the Pacific Northwest. These systems are identifiable in Figure 3.1 and diagrammatically represent:

1) Retail stores which receive chilled carcasses from the packer or a central distributor, and break them into retail cuts;
2) Retail stores which receive boxed primals from central

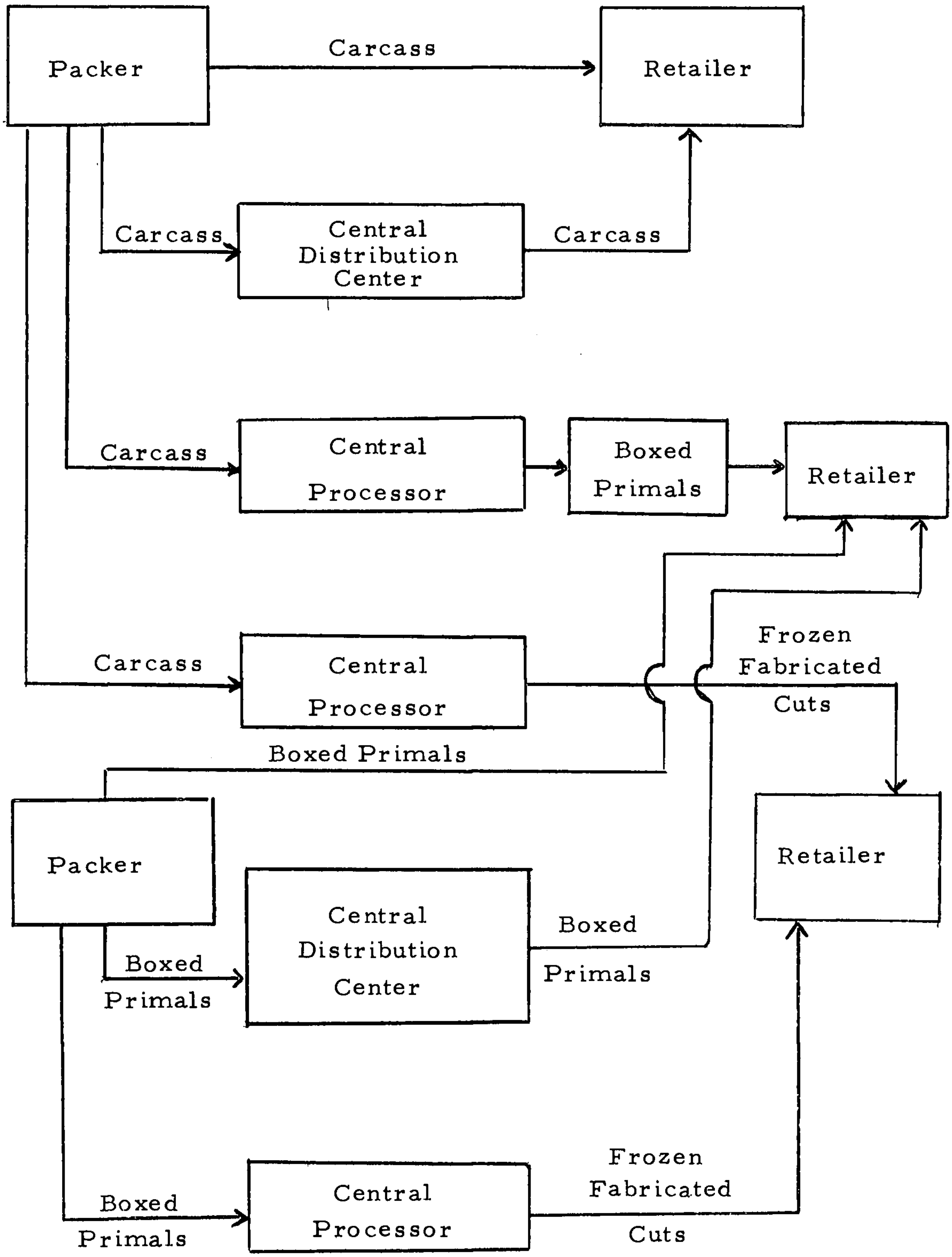

Figure 3.1. Alternative beef distribution systems.

distributors or packers for breaking and packaging as retail cuts;

3) Retail stores which receive both boxed primals and chilled carcasses, with the proportionality of each varying for each procurement decision period; and

4) The packer who breaks carcasses into retail cuts, freezes, wraps, labels, and ships to central distributors who in turn ship to retailers, or the packer may ship the frozen retail cuts directly to the retail store.

This intermediate distribution sector is always made up of at least two firms, and many times includes more. An overall rating of efficiency for each system was once envisioned by the author as a suitable thesis. However, after exploring the data requirments, it was soon obvious that, even though an overall rating may be interesting, and most useful, such an undertaking was beyond the many constraints of this particular project. The question then arose; What is a reasonable scope, considering both the constraints of the project and the usefulness of the research effort?

The present scope of the study was influenced by the fact that one particular sector of this intermediate system, the retailer, is currently receiving the most encouragement from industry sources to adopt the new technology associated with fabricated beef. This is certainly a reasonable place to focus attention, in that marketing decisions made as the product flows through the distribution channels, all culminate at the retail store. Based on this trend, it seems most appropriate, given the constraints of the project, to make the retail grocery firm the focal point of the study.

The study area for the thesis covers the states of Washington and Oregon. Table 3.1 is a descriptive analysis of retail grocery stores in each of the states and shows that total retail grocery store sales in the study area, account for almost four percent of the total retail food sales in the United States.

Table 3.1. Descriptive analysis of retail grocery stores in Oregon and Washington, 1972.

Description	Oregon	Washington
Retail food sales as a % of total U.S. food sales	1.6	2.3
Total number grocery stores	1,937	2,597
Chain	359	488
Independent	1,578	2,109
Total dollar sales/all retail grocery stores	$1,369,000,000	$1,978,000,000

Source: Supermarketing, September, 1973.

Table 3.2 shows that on a national basis, fresh meat, fish, poultry, and provisions represent 22.21 percent of total retail food sales in grocery stores. Retail food stores account for almost 58 percent of the value of all domestic consumption of meat products in the United States. Information on total domestic consumption and the percent purchased through retail grocery stores is not available for specific states, therefore no comparison of study area data and national statistics can be made. However, it will be assumed that approximately the same ratio prevails in both states under study.

Table 3.2. Value of domestic consumption of fresh and cured meat, fish and poultry in the United States, 1972.

Description	Value of Total Domestic Consumption	Value Sold in Grocery Stores	Percent of Total Store Sales
	(million dollars)	(million dollars)	
Fresh meat			
Beef	16,154.9	7,582.6	8.69%
Lamb	548.0	491.3	.56%
Pork	2,544.6	1,532.9	1.76%
Veal	1,129.6	571.8	.66%
Fish	716.8	596.9	.68%
Poultry	3,928.4	2,170.5	2.49%
Provisions	8,648.9	6,425.2	7.37%

Source: Supermarketing, September, 1973.

Since the objective of the study is to find the relative efficiency of alternative meat handling systems, it is necessary to establish the prevalence of each system in the study area. Three readily discernible systems are in operation: the traditional naked carcass system, the relatively new fabricated meat handling system, and the frozen meat system. Frozen meat has reached a very specific clientele and, because of its limited use, will not be explored in this study.[24/]

[24/] For further information see Youde and O'Connor (1973).

Therefore, the study essentially is reduced to a comparison of retail stores that handle naked carcass beef, and those that utilize a fabricated system.

One interesting generality provided by people in the meat distribution trade, and readily visible to an observer, is the diversity in the acceptance of the fabricated meat programs in the two states. In general, Oregon has remained with the traditional naked carcass distribution system, while retailers in the State of Washington have changed to the new technology of fabricated beef. This fact, provides an excellent opportunity for stratification of a sample. That is, each of the two areas have different technologies, yet neither area is in a state of transition with respect to accepting their particular method. This is rather important, in that the body of theory presented above is not intended to measure the diffusion of technological change, which might be the case if a sample contained retail stores that were in the process of converting to a new technological system.

Sample Size and Stratification

A stratified random sample of retail stores in each state was planned as a sampling technique. Since each state primarily uses one of the distribution systems, a sample from each state was to represent a respective distribution system, and both state samples were to be stratified by size as determined by the dollar sales of the meat department. An equal number of stores was to be selected from each state in each of three size categories, (1) less than $5,000 in meat sales per week, (2) between $5,000 and $10,000 in meat sales per week, and (3) over $10,000 in meat sales per week.

However, when representatives of each segment of the stratification were approached with a sample questionnaire, it was discovered that some of the data needed to complete the study was considered to be of a confidential nature. Therefore, either because of company policy, or personal preference, it was apparent that there would be limited cooperation from some segments of the industry. Because of this, it appeared that a random sample would not be the most appropriate sampling technique.

An alternative to random sampling was to find retailers who would cooperate, yet fit the general stratification requirements. It must simply be assumed that since the sample is not random, that the willingness to cooperate is independent of the efficiency indices that are to be estimated. In addition, both models, that have been previously described, are contingent on the data used in the analysis, and are not representative of the entire population.

The final sample is composed of 42 stores, 21 in Oregon that use the carcass distribution system for beef, and 21 in Washington that use a fabricated beef system. The sample distribution, classified by meat department sales, is shown in Table 3.3.

Table 3.3. Number of sample stores.

Description	Naked Carcass System	Fabricated System
Meat sales per week		
Under $5,000	7	6
$5,000-$10,000	7	7
Over $10,000	7	8
Total No. of stores	21	21

The sales of fresh and cured meat and poultry for the 42 sample stores as a percent of total store sales are shown in Table 3.4. There appears to be little difference between stores that use a carcass or fabricated system with respect to the product categories of beef, lamb, pork, and poultry. However, the "all other" category, which accounts for provisions, fish, and miscellaneous items, is smaller for stores that use the carcass system, 7.7 percent, than for stores using a fabricated system, 11.15 percent.

Table 3.4. Sales of fresh and cured meat and poultry as a percent of total store sales.

Description	Percent of Total Store Sales	
	Carcass	Fabricated
Fresh meat		
Beef	9.95	9.85
Lamb	.32	.32
Pork	2.80	2.22
Poultry	2.09	1.45
All other	7.70	11.15
Total meat sales	23.86	24.99

A comparison of data from the sample stores (Table 3.4) with national estimates of the same statistics (Table 3.2), may be used to put the Northwest sample in perspective. The sales of beef and pork as a percent of total store sales is higher in the Pacific Northwest than for the nation as a whole. Poultry and lamb sales are slightly lower. A direct comparison of the other categories can not be made. because of differences in items included in the two samples.

Variable Measurement

As previously discussed, the retail grocery firm is the focal point of this study. Operational records from the sample retail stores provide the preliminary data needed for analysis. More specifically, invoices of all meat purchases, sales records, meat department labor requirements, and an accurate description of all equipment in the meat department were collected for the sample retail stores to provide the empirical basis for estimating the efficiency indices. Some secondary information was also collected to aid in estimating variables for which primary data was unavailable.

The meat invoices of each store provide a description of each product purchased, the quantity purchased, and the price paid by the retailer. Invoices for the month of February, 1973, were utilized. This time period was chosen for several reasons. First, the federal price freeze on the retail price of meat that existed through most of

1973, had not yet been put into effect. The markets for beef, pork, lamb and poultry were essentially of a competitive nature, with no artificial constraints on supply or demand. Second, February meat sales historically have not exhibited much seasonal variation. This may be attributed to the fact that there are no "eating" holidays in February, and therefore, it represents an "average" month. And third, a one month period was selected because some chains summarize each store's purchases on a monthly (4 week) basis. For stores selected from these chains, the time required to record and summarize each invoice was eliminated, and the time and expense of data collection was reduced considerably.

An important assumption follows from establishing a month as a suitable time period; the beginning and ending inventory of the meat department is assumed to be the same. If this assumption was not made, it would be necessary to establish a beginning and ending inventory for each product. Since the data was collected <u>ex post</u>, inventories were unavailable for most of the sample stores. However, six of the 42 stores in the sample, had the beginning and ending total value of all meat products for the sample period. The average change in the total value for the six stores was -$63.18. This small change indicates that the assumption of no change in the inventories may be made without seriously biasing the sales data.

Store sales records were also collected for the month of February. Meat department sales are used as a proxy variable for measurement of scale. Other variables that might be used for a scale estimate, such as total square footage or sales area, were not used because of the lack of correlation between these variables and the quantity of product sold. This reflects the fact that there exists a considerable amount of over capacity in many retail meat markets.

Since retail sales records are not available for particular retail cuts of meat, an estimate of these sales must be made to determine the sales by species and product in the meat department. Secondary data available from the U.S. Department of Agriculture and industry sources were used in these estimations.

All of the sample stores that used the carcass system of handling beef, purchased U.S.D.A. Choice beef, or a house roll grade that the retailer assumed was very close to the U.S.D.A. Yield Grade 2. Table 3.5, shows composite percentage conversion factors that are used in this study to estimate the yield of retail cuts from each wholesale beef primal. This composite was calculated using yield estimates from U.S.D.A. Yield Grades for Beef (U.S.D.A., 1968) and A Steer's Not All Steak (Beef Industry Council, 1972).

Estimates of a conversion factor for fabricated beef were obtained from two chains in the State of Washington who had estimated the retail cut-out prior to this study. The yield of retail cuts from wholesale fabricated sub-primals averaged approximately 91 percent for the two chains.

Table 3.5. Conversion factors of wholesale primal beef to pounds of retail cuts.

Primal	Conversion Percentage
Chuck	83.9
Brisket	78.6
Shank	31.4
Short Plate	87.8
Flank	74.4
Rib	83.9
Loin	76.9
Round	63.7
Whole carcass	73.3

Source: This composite was calculated using data from: USDA Yield Grades for Beef (USDA, 1968) and A Steer's Not All Steak (Beef Industry Council, 1972).

An estimate of the retail yield from lamb was obtained from Smith and Carpenter (1972), and is 79.2 percent of the wholesale carcass weight. Since all lamb reached the retail stores in carcass form, this cut-out percentage is used for all stores. As discussed in the introductory chapter, pork and poulty arrive at the retail store in a form that results in very little loss in waste due to trim and shrinkage. Therefore, an estimate of 98 percent retail yield was used in converting the wholesale weight of pork and poultry to retail pounds.

Another variable that is not available from the retail stores, is the average weighted retail price of each of the commodities in the survey, beef, pork, poultry, and lamb. Again, these variables are estimated from industry and government data.

A composite price for beef is obtained by combining the retail price of individual cuts. The prices are combined by weighting the price of each cut by the yield or percent that the specific cut represents of the total salable retail cuts in a carcass. Twenty-nine retail cuts are used in computing this composite for beef. These cuts and their relative weights were obtained from the procedures used by the U.S. Department of Agriculture in determining their price-spread series (Duewer, 1970).

The prices of each of the retail cuts in each of the sample markets, were obtained from wholesale firms, who survey weekly the retail price of competitive independent and chain stores in their respective market areas. An average price for an area was estimated from the wholesale surveys, and weighted following the U.S.D.A. procedures discussed above. This constitutes the aggregate price classification for beef used in this study.

The U.S.D.A. procedures for estimating a composite retail price for pork could not be followed in this study. The government estimate is a composite of 20 retail cuts, including bacon and other provisions. Only fresh pork, i.e., prok chops and pork roasts, are included in this study as "pork". Since pork is shipped to the retail store in primal form, only certain retail cuts can be obtained from a specific primal, that is, only chops, loin roast, and country spare ribs can be obtained from a pork loin. Therefore, the quantity of each pork primal is used as the proportional weight in calculating the aggregate retail pork prices used in this study. The actual retail prices were obtained from the same wholesale sources described above for beef.

The aggregate retail price for lamb reflects the retail cut-out proportion of a full carcass, as described in Smith and Carpenter (1972). And, the retail price of poultry is simply the average price of cut up fryers. The actual retail prices for both of these products were also obtained from the wholesale surveys.

The aggregate retail prices for beef, pork, poultry, and lamb, for each of the market areas in this study are shown in Table 3.6. The retail price level is higher in the survey stores in Washington, for beef and pork, while the price of poultry and lamb is the same.

Table 3.6. Average aggregate retail price for beef, pork, lamb and poultry.

	Weighted Average Price per Pound	
Commodity	Carcass	Fabricated
Beef	1.1455	1.2912
Pork	1.2013	1.3407
Poultry	.59	.59
Lamb	1.278	1.278

Labor is another primary input in the meat department, and is considered a variable input, even though unionized institutional constraints exist with respect to the differing quantities of labor that management may employ over a given time period for each employee. These restrictions make labor a rather "lumpy" input. Weekly labor requirements were collected for the month of February for all personnel engaged in the actual operation of the meat department. The quantity and quality of management and other store personnel is assumed not to affect the efficiency indices in any other manner than a neutral form. That is, the affect of management and other store personnel is assumed to remain constant across all firms in the sample. The cost of labor, is simply considered to be the wage rate set forth in the union contract for each respective state. This implies that the fringe benefits, which must be paid by the employer, remain constant across all firms in both unions.

The capital employed in the meat department is the final variable to be estimated for each retail store in the sample. The measurement of capital assets in a cross-sectional survey presents some conceptual and operational difficulties. Conceptually, only the service flow from fixed capital should be considered as an input in the present production period. However, in practice, the value of the stock of capital has often been used as a proxy for the service flow, or alternatively, a simple depreciation rate has been used to represent this service flow. This practice is legitimate only in a special case. Yotopoulos (1967, p. 476) points out the fallacy of this approach and also shows that a correct measure can generally be estimated from available data.

The flow of capital services in a certain time period, in this study, one month, is approximated in a perfect market by the rental price of the asset per unit of time, times the units worked in a month. Unfortunately, data of this kind are not usually available. However, Yotopoulos points out that other data, such as the initial investment or survey data of current market value of the stock are usually available, and can be used in estimating the service flows.

The use of a stock proxy for a service flow is justified only on the basis of an assumption that the stock be proportional to the flow.[25/] However, this assumption of proportionality seldom holds. Most capital items produce a variable flow of services over the life of the asset and some stocks also deteriorate over time. In addition, these changes may be at a different rate. Holloway (1972) summarizes Yotopoulos' results as follows:

1) When the service flow of an asset with a finite life span is constant over time, the use of stocks instead of flows places more weight on the more durable asset;

[25/] Yotopoulos proves this theorem and gives examples of common violations of the assumption (1967).

2) When the service flow of an asset with a finite life span deteriorates with time, the use of stocks instead of flow places even more weight on the more durable asset, than in the case of a constant service flow;
3) In a case such as livestock, a varying weight from stocks to flows may result where assets first appreciate with age and then depreciate;
4) Whan an asset has an infinite life span, such as land, stocks will remain proportional to flows.

The capital used in the meat department is mostly refrigerated storage and display equipment, plus equipment used to prepare and package the retail cuts. An estimated average cost for capital of a meat department designed to accommodate $5,000 weekly meat sales is about $23,000. A meat department designed to do $10,000 to $12,000 weekly meat sales will have an average cost of $33,000. It should be pointed out that the capital requirements for stores using the carcass and fabricated meat handling systems are almost identical. The only cost that could be eliminated in a fabricated system, is the overhead meat rail that is necessary to transport hanging carcasses from a receiving area to storage and ultimately to the preparation area. This railing costs approximately $12.50 a linear foot, and in most stores will total about $1,000. Because of this small additional cost, most stores that use the fabricated system retain the rails so that carcass beef can be handled if necessary.

Keeping Yotopoulos' flow arguement in mind, the service flow of capital was estimated using

$$\bar{R} = \frac{rV_0^T}{1-e^{-rT}}$$

where

$\bar{R}$ = constant service flow

V_0^T = present value of a new asset with useful life of T years

r = discount rate.

The original market value of the asset was obtained from the retail store accounting records. It was assumed that the average useful life of the asset was 15 years, and the asset had no salvage value at the end of that time. The only variable left to estimate is r, the discount rate.

The discount rate can be viewed as the opportunity cost for a fixed input. That is, if resources invested in the food industry earn unusually high returns, competition will rapidly increase in a competitive industry, while on the other hand, if earnings are low, there will be a tendency of firms to leave the industry, or at least for new firms not to enter. Profit as a percent of net worth is one measure of an industry discount rate, and is available from secondary data sources. A sample of 20 food chains listed in <u>The Value Line</u>

Investment Survey (1974) indicated that an average profit on net worth ratio for 1973 was 15 percent. It is assumed that this same ratio is true for independent and chain stores in this study.

Another variable that was initially considered in the model was an estimate of the rent for the meat department in the retail store. As the survey progressed, it was learned that there was a great amount of deviation in the actual use of "meat department" space, and that many stores could not estimate any rental value for the meat department. Therefore, the variable was dropped from the model, and it was assumed that any bias created by this omission will be constant across firms.

Aggregation

The discussion of economic models and measurement of variables has proceeded with very little regard for the problems of aggregation. However, as in most production studies, the problems exist and must be dealt with. Henri Theil lists three types of aggregation that should be considered; (1) Aggregation over individuals, (2) Aggregation over commodities, and (3) Aggregation over time periods (1954, p. 3). The first two types of aggregation are relevant to this study and will be discussed below. Aggregation over individuals refers to the combination of individual firms in order to derive an estimate of the aggregate production function for a given commodity. There are an infinite number of levels of aggregation, cities, counties, states, firms, or industries, to name a few. In estimating the efficient production function and the corresponding relative efficiency indices, the level of aggregation is important.

For example, consider the Farrell method of estimating an efficient unit isoquant for two different levels of aggregation. If data are collected from a sample of firms in several different states, the estimate of the efficient unit isoquant as derived from the individual firm data will not be the same as an estimate derived from the aggregate state data. The state data will be an average of the firms within each state and will contain both efficient and inefficient observations. In other words, the state estimate of the efficient unit will be more pessimistic than an estimate made on the basis of individual firms.

A similar argument will hold true for the average estimation procedure. Since least squares is used to estimate the regression line, a line fit to the state data will not have the same slope and intercept as a line fit to the individual firm data. Therefore, when interpreting an estimated production function and resulting efficiency ratings, the level of aggregation must be considered. The estimates will only be appropriate for the level of aggregation on which the study is based.

Aggregation over commodities refers to the combination of two or more separate economic factors of production. This type of aggregation is common in production studies and is usually made when data are not available on all the separate factors, or data are not available to explain the relationship between the separate factors. A common example is labor, where labor is measured in hours, even though no two individual laborers may be identical in their productivity.

The effect of aggregation over commodities can be seen by considering labor in the following example. While every individual is different in many respects, labor can be broken into various job categories. That is, while no two men are the same, it is possible that in terms of performing a certain task, numerous men may be equally proficient. It is the categories of laborers which may be considered different in an economic sense. For example, consider firms using two classes of labor, with efficiency measured using the Farrell method. Assume further, that equal amounts of all other factors of production are used, so that the aggregation of labor can be visualized independently of all other input factors. Table 3.7 is used to further illustrate this hypothetical case. When the technical efficiencies are compared, the aggregate data produces only one firm which is 100 percent efficient (TE = 1). However, when the disaggregated data are used, five firms are rated as 100 percent efficient (TE = 1). The simple summation manner in which the inputs were aggregated in the example above, will only produce the correct measures of efficiency when the factors are perfect substitutes. However, when the factors are not perfect substitutes, the correct efficiency index can be computed, if the factors are weighted by the marginal rate of technical substitution between the factors, as reflected by the slope of the isoquant.

Table 3.7. Hypothetical example of the impact of aggregation of two factors of production.

Firm	L_1	L_2	TE_1	$L_1 + L_2$	TE_2
1	12	0	1.00	12	**
2	10	1	1.00*	11	**
3	8	2	1.00	10	1.00
4	6	5	1.00	11	**
5	4	10	1.00	14	**
6	9	2	**	11	**
7	8	4	**	12	**
8	6	8	**	14	**

* Firm 2 is simply a linear combination of firms 1 and 3.
** Technical efficiency is less than one.

In a practical manner, an appropriate level of aggregation for a particular case depends on the conceptual view of the research question for which answers are being sought. The researcher must decide if there exists a trade-off between some inaccuracy due to aggregation bias, and the cost of attempting to do the analysis at a different level. These decisions, once made, should then be conveyed explicitly to the reader.

In this study the firm is used as the unit of observation. The production function is assumed to produce one commodity, retail meat, which is composed of beef, pork, lamb, and poultry. These products are all sold by weight, and the quantity of each was estimated following the procedures previously described. An average weighted retail price of meat for each firm was computed by simply multiplying the retail price of each product, as listed in Table 3.6, by the total retail pounds of each product sold by the firm in February, and dividing this mathematical product by the sum of the total retail pounds of each product.

The inputs included in this study are, wholesale meat, labor, and capital. The quantity of wholesale meat is simply the sum of the quantity of beef, pork, lamb, and poultry as computed from the invoices of the retail firms. A weighted average wholesale cost of meat was computed in the same manner as described in estimating the retail price, except wholesale quantities and prices of each product were used. The quantity of labor used in the meat department is measured by the man hours charged to the meat department by each firm. The cost of labor is simply the average wage per hour for each particular firm. The last input to be considered is capital. The service flow of the capital assets, as previously discussed, is used to measure this variable.

Another variable used in the analysis is the weekly meat sales of each firm. This variable is used as a proxy for the scale, or size, of the firm. The data for this variable were collected from the weekly sales records of each firm.

Functional Forms and Estimating Techniques

Technical, pricing, and economic efficiency of retail meat operations as measured by a frontier and a profit function estimation technique serve as the basis for analysis in this study. The Farrell method, using a programming model described by Boles (1971), is used in estimating the frontier technical efficiency. A profit function, taking the Cobb-Douglas function form as described by Lau and Yotopoulos (1971), serves as an alternative estimate of relative efficiency measures.

The Farrell Model

Boles programming model for calculating a Farrell frontier simply translates Farrell's theory into a linear programming formulation. Consider each of n firms as a separate activity producing a unit of output through the input of m factors of production. The jth activity is completely described by a vector of $m+1$ elements, and f_{ij} represents the quantity of factor i used in the unit activity j. The objective is to determine the location of each firm j; relative to all n firms in the input space.

The essential question to be asked about each activity, then, is the following: Given the n activities and the jth list of inputs, what is the maximum amount of output that can be produced? By definition, the jth activity produces one unit of output. If some combination of activities can produce more than one unit while using no more resources than the jth activity, then the jth activity is inefficient, and the efficiency index is defined as the reciprocal of maximum output. Formally, then, there are n distinct linear programming problems in which the n productive activities form a constant coefficient matrix, A, and each of the activities in turn furnishes the coefficients of the "right-hand side," rhs. In this study, each retail store is a productive activity. Let V be an n x 1 vector of ones. The jth linear programming problem is:

$$\text{Maximize} \qquad X_0 = V'X$$

$$X \geq 0$$

$$AX \leq P_j$$

Let $\overline{X}_0$ be the optimum value of the objective function; then the efficiency index is $1.0/\overline{X}_0$. The set of convex combinations of the optimum basis defines one facet of the technical efficient unit isoquant

(Boles, 1966, p. 137-38.

The Farrell model as presented above, assumes constant returns to scale. If this assumption is relaxed, the Farrell and Fieldhouse (1962) method of estimating the production function can be used. Seitz gives the following algebraic description of this model. Assuming n firms producing a single output from m factors of production, n vectors $P_j = [S_j Y_{ij}]'$ where S_j = scale, Y_{ij} = unit factor utilization, $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$ can be defined. Each firm is set as the "right-hand side" of n distinct linear programming problems. Solving for one firm, P_e, the problem is to

$$\text{Maximize} \quad X_0 = \Sigma X_j \tag{3.1}$$

$$\text{Subject to:} \quad X_j \geq 0$$

$$\sum_{j=1}^{n} X_j(P_j - S_E E_1) = (P_e - S_E E_1) = 0 \tag{3.2}$$

where $E_1 = [1.0, 0.0, \ldots, 0.0]'$. Let $\overline{X}_0$ be the optimum value of the objective function, where ΣX_j is the output for a given level and combination of inputs, then the technical efficiency given scale (TES) for firm P_e is $1.0/\overline{X}_0$. Upon the solution of n problems, the efficient unit isosurface (EUIS) is defined in terms of the activities for which TES = 1 (Seitz, 1970, p. 509).

Boles (unpublished monograph) notes that the strict Equation (3.2), requires that, if P_j is inefficient, the set of activities defining an efficient basis must have a weighted average scale equal to the scale of the activity P_j. Furthermore, since the scale relationship is a strict equality, the associated shadow price is not constrained to be nonnegative. The sign of this imputed price can be used as an indicator of the presence of economies or diseconomies of scale for the size of operation and factor proportions used by P_j. If the shadow price is negative, this implies that maximum output would be increased if the corresponding slack were added to the basis. This further implies that the efficiency index would be reduced if P_j were compared to a nonnegative linear combination of the optimal basis activities having a smaller scale than P_j. Consequently, a positive price implies increasing returns to scale while a negative prive implies decreasing returns to scale.

This scale equality restriction can also be tied directly to the earlier theoretical discussion concerning the comparison of firms of different scale. Because of the restriction, there will be an many different unit isoquants as there are different scales of operation. Thus each firm is classified relative to other firms of the same size, and small size firms will not be described as inefficient, simply because they are compared to large size plants.

The variables of this study that are used in measuring technical efficiency can be described by the following set of n partitioned vectors:

$$P_j = \begin{bmatrix} Q_j \\ \hdashline X_{ij} \\ \hdashline S_j \end{bmatrix} \qquad j = 1, 2, \ldots, n,$$

where:

Q_j = a single element representing the total pounds of meat sold by the jth store.

X_{ij} = the rate of input of the ith factor of production, and

X_{1j} = wholesale pounds of meat purchased by the jth store,

X_{2j} = total man hours of labor used by the jth store,

X_{3j} = service flow of capital for the jth store.

S_j = single element representing the scale of the jth firm, as measured by the weekly meat sales of the firm.

The input for the two types of problems discussed earlier, the Farrell approach and the Farrell and Fieldhouse approach, respectively, differ only by the scale element, S_j, which is present only in the latter case.

Given these two linear programming models, and the prices of the inputs of the models, ten efficiency indices can be generated. Technical efficiency assuming constant returns to scale (TEC), is obtained from the Farrell model. Technical efficiency given scale (TES), is derived from the Farrell and Fieldhouse model.

Assuming constant returns to scale, price efficiency (PEC) and economic efficiency (EEC) are calculated by multiplying the unit factor utilization of the inputs by their respective prices and then summing this mathematical product. This yields the unit cost of production for each firm. The minimum unit cost of production can then be determined. The ratio of the minimum unit cost to the unit cost of a particular firm gives the economic efficiency (EEC). Price efficiency (PEC) is then obtained by residual, the ratio EEC to TEC.

Price efficiency (PES) and economic efficiency (EES) given scale, is calculated in a similar manner to PEC and EEC, in that the unit cost of production is determined as above. However, in the case of PES and EES, the minimum unit cost of production for each scale of firm is determined. The ratio of the minimum unit cost for each scale to the unit cost of each firm of the same scale, gives the economic efficiency (EES). PES is simply the ratio of EES to TES.

Technical scale efficiency (TSE) measures the relative efficiency of different scale activities due to the physical nature of the production function. This measure of technical efficiency is derived from the efficiencies given scale. A set of n^* observations for which EES equals one is selected, and defines a vector $P_j = [X_{ij}]'$, where the

X_{ij}'s are the unit utilizations of the inputs and $j = 1, 2, \ldots, n*$. The linear programming mode which is used in the case of constant returns to scale is again utilized. The level of TSE is simply the technical efficiency generated from this subset of data. The levels of TSE for the observations not included in this subset are found by interpolation between the value of TSE of the observations in the subset with immediately larger and smaller scale. The ESE of the subset of observations ($n*$, where EES = 1) equals the ratio of the minimum unit cost of production over the subset to the unit cost of the remaining activities. As defined above, the price efficiency (PSE) is equal to the ratio ESE/TSE. As in the case of TSE, the levels of PSE and ESE for the remaining firms not in the subset are found by interpolation.

Economic efficiency (EE) for each firm is equal to the product EES * ESE. This is equivalent to the ratio of the minimum unit cost of production to the unit cost observed for each of the remaining firms in the sample.

The Profit Model[26/]

A general description of the UOP profit model and its related measures of efficiency was presented above. The purpose of this

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[26/] This section is summarized from Yotopoulos and Lau (1973).

section is to give the profit function a specific functional form, the Cobb-Douglas, and to show the derivation of the factor demand functions. The profit and factor demand functions provide the analytical tools to derive the efficiency measures.

The Cobb-Douglas production function with decreasing returns in variable inputs is given by

$$V = A \prod_{i=1}^{m} X_i^{\alpha_i} Z_i^{\beta_i} \tag{3.3}$$

where

$$\mu \equiv \sum_{i=1}^{m} \alpha_i < 1 \text{ . } 27/$$

The UOP profit function for the Cobb-Doublas production function is

$$\pi^* = A^{(1-\mu)^{-1}} (1-\mu) \left[\prod_{i=1}^{m} \left(\frac{c_i}{\alpha_i}\right)^{-\alpha_i(1-\mu)^{-1}} \right] \times \left[\prod_{i=1}^{n} Z_i^{\beta_i(1-\mu)^{-1}} \right] . \tag{3.4}$$

The actual UOP profit function for this Cobb-Doublas production function for firm i, with efficiency parameters A^i and k^i is

27/ The restriction $\mu < 1$ is required since constant or increasing returns in the variable inputs are inconsistent with profit maximization.

$$\pi_a^i = A^{i(1-\mu)^{-1}} \left(1 - \sum_{j=1}^{m} \alpha_j/k_j^i\right) \left[\prod_{i=1}^{m} (k_j^i)^{-\alpha_j(1-\mu)^{-1}}\right]$$
$$\times \left[\prod_{j=1}^{m} \alpha_j^{\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{m} (c_j^i)^{-\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{n} (Z_j^i)^{\beta_j(1-\mu)^{-1}}\right] \tag{3.5}$$

It can be pointed out that the two firms differ by a constant factor, which is a function of the k_j^i's and A^i's , so (3.5) can be rewritten as

$$\pi_a^i = A_*^i \prod_{j=1}^{m} (c_j^i)^{\alpha_j^*} \prod_{j=1}^{m} (Z_j^i)^{\beta_j^*} \tag{3.6}$$

where

$$A_*^i \equiv A^{i(1-\mu)^{-1}} \left(1 - \sum \alpha_j/k_j^i\right) \left[\prod_{j=1}^{m} (k_j^i)^{-\alpha_j(1-\mu)^{-1}}\right]$$
$$\times \left[\prod_{j=1}^{m} \alpha_j^{\alpha_j(1-\mu)^{-1}}\right] .$$

Furthermore, the following relations exist:

$$k_*^i \equiv \left(1 - \sum_{j=1}^{m} \alpha_j/k_j^i\right) (1-\mu)^{-1} \tag{3.7}$$

$$\alpha_j^* \equiv -\alpha_j(1-\mu)^{-1} < 0 \qquad j = 1, 2, \ldots, m \tag{3.8}$$

$$\beta_j^* \equiv \beta_j(1-\mu)^{-1} > 0 \qquad j = 1, 2, \ldots, n \tag{3.9}$$

The derived demand functions for variable inputs are given by

$$X_i^* = -\frac{\partial \pi^*}{\partial c_i} \qquad (3.10)$$

Multiplying both sides of (3.10) by $-c_i/\pi^*$, gives

$$-\frac{c_i x_i^*}{\pi^*} = \frac{\partial \ln \pi^*}{\partial \ln c_i} \qquad i = 1, 2, \ldots, m$$

which for the Cobb-Douglas profit function becomes

$$-\frac{c_i x_i^*}{\pi^*} = \alpha_i^* \qquad (3.11)$$

The demand functions for variable inputs corresponding to the UOP profit function given in (3.4) is

$$X_\ell^i = A^{i(1-\mu)^{-1}} (\alpha_\ell / k_\ell^i c_\ell^i) \left[\sum_{j=1}^{m} (k_j^i)^{-\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{m} (\alpha_j^{\alpha_j})^{(1-\mu)^{-1}}\right]$$

$$\times \left[\prod_{j=1}^{m} (c_j^i)^{-\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{n} (Z_j^i)^{\beta_j(1-\mu)^{-1}}\right]$$

$$i = 1, 2, \ldots, n$$

$$\ell = 1, 2, \ldots, m$$

or

$$X^i_\ell = -A^i_* \alpha^*_\ell (k^i_\ell)^{-1} (c^i_\ell)^{-1} (k^i_*)^{-1} \left[\prod_{j=1}^{m} (c^i_j)^{\alpha^*_j}\right] \left[\prod_{j=1}^{n} (Z^i_j)^{\beta^*_j}\right] \quad (3.12)$$

$$i = 1, 2, \ldots, n$$

$$\ell = 1, 2, \ldots, m .$$

By substitution from Equation (3.6) and the derivation which led to Equation (3.11) the demand equations can take the form

$$\frac{-c^i_\ell X^i_\ell}{\pi^i_a} = (k^i_\ell)^{-1} (k^i_*)^{-1} \alpha^*_\ell = \alpha^{*i}_\ell \quad (3.13)$$

It should be pointed out that the demand functions also differ across firms by constant factors.

The estimating equations for this study are (3.6) after taking the natural logarithms of the function, and (3.13). Taking the natural logarithms of (3.6), and assuming, as an example, two firms, the equation for each firm takes the form

$$\ln \pi^1_a = \ln A^1_* + \sum_{i=1}^{m} \alpha^*_i \ln c^1_i + \sum_{i=1}^{n} \beta_i \ln Z^1_i ,$$

and

$$\ln \pi^2_a = \ln A^1_* + \ln \frac{A^2_*}{A^1_*} + \sum_{i=1}^{m} \alpha^*_i \ln c^2_i + \sum_{i=1}^{n} \beta_i \ln Z^2_i ,$$

respectively. If the two firms have identical relative economic efficiency, the two functions π_a^1 and π_a^2 should be identical. This implies that $(\ln A_*^2/A_*^1)$ is equal to zero. This can be tested by utilizing a firm dummy variable in the logarithmic UOP profit function and testing whether its value is equal to zero. For the specific variables in this study the equations take the form

$$\ln \pi_a^i = \beta_0 + \beta_1 D_1 + \alpha_1^* \ln c_1 + \alpha_2^* \ln c_2 + \beta_1^* Z_1 + \ln e \qquad (3.14)$$

where

π_a^i = actual UOP profit for each meat department. This is the total revenue less total variable cost, divided by the price of output (aggregate retail price of meat).

D_1 = dummy variable for a specific firm. 1 if for firm 2, 0 if for firm 1. This is equivalent to using $\ln D_1$ where D_1 is 10 if for firm 2, 1 if for firm 1.

c_1 = normalized aggregate wholesale price for meat

c_2 = normalized wage rate

Z_1 = service flow of capital.

The derived demand functions differ across firms by a constant and, maintaining the assumption of two firms, used in the example above, the demand function (3.13) can be written for input ℓ as

$$\frac{-c_\ell^i X_\ell^i}{\pi_a^i} = \alpha_\ell^{*1} + \alpha_\ell^{*2} D_1 \qquad (3.15)$$

where

c_ℓ^i = the normalized variable input, and in this study

c_1 = normalized wholesale price of meat

c_2 = normalized wage rate

X_ℓ^i = quantity of each variable input;

X_1 = pounds of wholesale meat

X_2 = meat department man-hours

π_a^i = actual UOP profit for each meat department

D_1 = dummy variable for a specific firm.

The estimating techniques and their specific functional forms, described above, will be used in the following chapter to test a set of hypotheses concerning the relative measures of efficiency.

IV. STATISTICAL RESULTS

Introduction

This chapter presents the quantitative results from a sample of 42 retail stores using the two efficiency models previously described. Preliminary observation of the data indicates that some modification of the sample size and the initial conceptual overview must be made before efficiency indices can be computed. These observations and model modifications are discussed below. Once these modifications have been made, estimates of the efficiency indices, and tests of the relevant hypotheses are shown. The chapter concludes with a discussion of the economic implications pertaining to efficiency, technological change and the rate of diffusion of carcass and fabricated beef handling systems of retail stores.

Summary of the Survey Data and Model Specifications

A summary of the survey data for the 42 sample retail stores is presented in Appendix A. After the survey was completed and the sales parameters of the firms were estimated, one fact stood out from the data. Five firms that were originally classified as small, less than $5,000 weekly meat sales, had failed to make a positive profit for the month of February. Additional contact with meat industry personnel confirmed that this was not an unusual result.

This result presented a practical problem with respect to the use of these five observations in the Cobb-Douglas profit model. Since the natural logarithm of the normalized profit is the dependent variable in the Cobb-Douglas model, and the natural log of a negative value does not exist, these five observations must be omitted. In addition, a later test of homoskedasticity indicated that the variance of small stores was statistically greater than the variance associated with medium and large stores. This finding is not unusual when working with cross sectional microeconomic data. In turn, the deletion of the five observations led to an inadequate stratified subsample to represent small stores. How can these problems be solved?

The choice at this point, was to either obtain additional samples of small stores, or to change the conceptual model to include only medium and large firms. After examining the survey data, it was decided to make two changes in the conceptual model, and to use the original sample data for analysis. The two changes involved; (1) changing the model to include only medium and large retail stores, and (2) changing the dimensions of the size stratifications. That is, in the original model, medium stores were defined as having weekly meat sales of \$5,000 to \$10,000 per week, and large stores having meat sales of over \$10,000 per week. The objective then, was to determine how the size stratification could be changed to include as many stores with positive profits as possible, yet prevent serious bias to the sample. It was finally decided to leave the large store grouping as it was in the original model, and expand the size stratification for medium stores by extending the lower boundary for meat sales from $5,000 to $4,000 per week. This new boundary was chosen to produce a medium classification having homoskedastic residuals with respect to size.

This decision resulted in the loss of 10 observations, five stores with negative profits and five heteroskedastic stores with weekly meat sales below $4,000. The total sample is now composed of 32 firms, 17 medium and 15 large retail stores. These 32 firms represent 14 stores that use the carcass beef handling system and 18 stores which utilize the fabricated handling system. A listing of the survey data for these 32 stores used in the frontier model and the profit model is presented in Appendix B.

A larger sample size would of course be preferable. However, the reader should recall an earlier discussion pointing out that the sample was limited in size by the unwillingness of some stores to disclose confidential information, and by the small total number currently using fabricated handling systems. When a shift in technology is being investigated a small sample size is not unusual.

The decision to modify the conceptual model in the manner described above, was made knowing that few conclusions could be made concerning small stores. It is clear that the small stores in the original sample, as a group, had a lower economic efficiency than medium or large stores. However, nothing can be said concerning technical or pricing efficiency. Unfortunately, this group of stores may have a greater need for research concerning meat handling systems, than the remaining firms which will be analyzed in this study.

Estimates of Relative Efficiency--
The Frontier Model

Introduction

The restrictive assumption of a linear homogeneous production function, and the bias that may result in estimating the efficiency indices from the Farrell model was discussed by Seitz (1970) in Chapter II. This analysis will begin by relaxing the assumption of linear homogeneity in an attempt to use the Farrell and Fieldhouse model to estimate the relative technical, pricing and economic efficiency indices given scale.

The Farrell and Fieldhouse model estimates the efficient unit isosurface, (EUIS) which is an approximation of the production function for the handling of meat products in a retail store. By definition, this function or surface defines the minimum input-output ratios for alternative combinations of factors of production and scales of operation. The level of TES estimated for each firm is a function of the relative distance from the scale axis to the EUIS and the point being rated. The overall shape and level of the EUIS is determined by the state of knowledge, and implementation of that knowledge relative to the handling of meat at the wholesale-retail level of the distribution channel. This state of knowledge is reflected by the most efficient firms included in the sample. The distribution of efficiency ratings, therefore, provides an indication of the performance of all firms sampled, relative to the most efficient firms.

The shape of the EUIS and the relative factor prices will result in varying levels of PES for the firms included in the sample. Meat departments utilizing the combination of factors which minimize cost, given the scale at which they are operating, will be rated efficient. As in the case of technical efficiency, the distribution of the price efficiency ratings can be utilized to determine the impact of various production techniques.

Economic efficiency given scale (EES), the product of TES and PES, can also be analyzed to determine the joint impact of the alternative production techniques. If a technique offers significant improvement either technologically, or in terms of pricing efficiency, the significance should be reflected in the estimate of EES.

The reader should recall that the previous discussion implicitly assumes that the production functions for alternative production techniques are exactly the same, or vary in a neutral fashion if one technique is technically more efficient than another. If this assumption is violated, the results of measuring relative efficiency via the frontier model will be inconclusive.

Relative Efficiency--Farrell and Fieldhouse Method

Two production techniques have previously been identified and discussed, a carcass handling system and a fabricated beef handling system. The question is: Is there any difference between the technical, pricing and economic efficiencies of the two handling systems? To investigate this question, the efficiency indices for firms using each respective distribution system can be compared. The relevant null hypothesis is: The two samples come from the same population. This simply means there is no difference between the two handling systems. Rejection of the null hypothesis implies that the distribution of the sample, deviates from the theoretical frequency distribution more than would be expected due to random variation, at the level of significance indicated. A Chi-square test is used to test this null hypothesis, and the theoretical frequency distribution of efficiency indices is determined on the basis of the distribution of the efficiency ratings for all of the 32 stores sampled.

Given the sample size N, and a $r \times s$ contingency table, the test statistic μ which has a Chi-square distribution under the null hypothesis is

$$\mu = \sum_{r} \sum_{s} \frac{(\text{observed - expected})^2}{\text{expected}} \quad .$$

To obtain a reliable approximation of the χ^2 distribution, two parameters are needed. One is the degree of freedom and the other is the number of observations (n) in each cell of the contingency table. It should be noted that $\Sigma n = N$. A $r \times s$ contingency table has $(r-1)*(s-1)$ degrees of freedom. Yamane (1964) points out various proposals regarding the sample size n in each cell.

> Cramer states that when the expected frequencies are larger than 10, we have a good approximation. Snedecor states that when the observed frequencies are less than 5 in any cell, the approximation of the χ^2 distribution becomes poor. H. Walker sets up a practical rule of thumb that when there are 2 or more degrees of freedom, and when each cell has 5 or more observations, the χ^2 table gives a good approximation to the exact probabilities (Yamane, 1964, p. 599).

This rule of thumb will be applied, when possible. Tables 4.1, 4.2, and 4.3, show the frequencies for each sample group and each level of technical, pricing and economic efficiency given scale, respectively. Many of the n cells have only one observed sample store. Therefore, it is necessary to group the efficiency levels so that there are at least five observations in each cell. Three natural groupings seemed to emerge from the data, firms with efficiencies of 1.000, .980 to .999, and less than .980. The total number of stores (n) for each of these groupings is shown in Table 4.4.

Table 4.1. Technical efficiency given scale (TES) ratings for retail stores using carcass or fabricated beef handling systems.

TES Rating	Carcass Handling System	Fabricated Handling System	Total Number of Firms (n)
1.000	6	11	17
.999		2	2
.997		3	3
.994		1	1
.983		1	1
.979	1		1
.969	1		1
.965	1		1
.960	1		1
.948	1		1
.938	1		1
.932	1		1
.916	1		1
Total	14	18	32

Using the grouped efficiency ratings to establish the probability distribution of the hypothetical population, the null hypothesis can be restated in probability terms as: Both carcass and fabricated beef handling systems have the same probability distribution, which is the probability distribution of the population.

Table 4.2. Price efficiency given scale (PES) ratings for retail stores using carcass or fabricated beef handling systems.

PES Rating	Carcass Handling System	Fabricated Handling System	Total Number of Firms (n)
1.000		5	5
.999		1	1
.998	1	2	3
.992	1		1
.988		3	3
.980		1	1
.977	1		1
.975	1		1
.974		1	1
.973		1	1
.971		1	1
.969		1	1
.963		1	1
.961		1	1
.957	2		2
.953	2		2
.949	1		1
.943	1		1
.939	1		1
.938	1		1
.933	1		1
.926	1		1
Total	14	18	32

Table 4.3. Economic efficiency given scale (EES) ratings for retail stores using carcass or fabricated beef handling systems.

EES Rating	Carcass Handling System	Fabricated Handling System	Total Number of Firms (n)
1.000		4	4
.999		1	1
.998		1	1
.997		2	2
.988		2	2
.985		1	1
.980		1	1
.977	1		1
.973		1	1
.971		2	2
.963		1	1
.960		1	1
.957	2		2
.953	1		1
.947		1	1
.936	1		1
.933	1		1
.929	1		1
.926	1		1
.925	1		1
.914	1		1
.906	1		1
.903	1		1
.900	1		1
.893	1		1
Total	14	18	32

Table 4.4. Frequency distribution for technical, pricing and economic efficiency given scale for grouped ratings.

Grouped Efficiency Ratings	Total Number of Firms (n)		
	TES	PES	EES
1.000	17	4	5
.980 to .999	7	8	9
less than .980	8	20	18
Total	32	32	32

The Chi-square test statistics for this null hypothesis with respect to technical, pricing and economic efficiency are shown in Table 4.5. For two degrees of freedom and $\alpha = 5$ percent level of significance

$$P(5.99 < \chi^2 < \alpha) = .05$$

and the rejection region is $\chi^2 \geq 5.99$. That is, if μ is larger than 5.99 the null hypothesis will be rejected. Table 4.5 shows that μ for TES, PES, and EES, is 16.223, 11.348, and 14.930, respectively. Hence, in each case, the null hypothesis that both samples, stores with carcass or fabricated beef handling systems, came from the same population, is rejected. This indicates that the mean and, or the variance of TES, PES and EES, for stores using the carcass beef handling system are different from stores using the fabricated handling system.

Table 4.5. Chi-square test of homogeneity for retail stores with carcass or fabricated beef handling systems.

Efficiency Measure	μ^*	χ^{2**}
TES	16.223	5.99
PES	11.348	5.99
EES	14.930	5.99

* $\mu = \sum_r \sum_s \frac{(\text{observed - expected})^2}{\text{expected}}$.

** This is the χ^2 value for 2 degrees of freedom and a probability level of α = 5 percent.

The previous results indicate that the samples come from two different populations, but does not indicate anything about the mean or variance for the respective sample. A relevant question may be: Is there any difference between the means of the two populations? Given the two independent samples, the t-distribution may be used to test the null hypothesis, H_0: $\overline{X}_1 = \overline{X}_2 = 0$. The use of the t-distribution in testing the significance for the difference between the means of the two independent samples assumes that the means are normally distributed and that the two population variances are the same. However, many times the equality of the population variance is suspect. When the variance is not the same, all is not lost. Snedecor and Cochran (1967) point out that the formula for the variance of $(\overline{X}_1 - \overline{X}_2)$ in independent samples still holds when the ordinary t is replaced by the quantity

$$t' = (\bar{X}_1 - \bar{X}_2) / \sqrt{s_1^2/n_1 + s_2^2/n_2} \ .$$

This quantity does not follow the Student's t-distribution when $\mu_1 = \mu_2$. The following conservative rule of thumb can be followed:

Case 1: $n_1 = n_2$. With $n_1 = n_2 = n$, the variance in the denominator of t' is $(s_1^2 + s_2^2)/n$. But this is just $2\ s^2/n$, where s^2 is the pooled variance. Thus in this case, $t' = t$. The rule is: calculate t in the usual way, but give it $(n-1)$ d.f. instead of $2(n-1)$.

Case 2: $n_1 \neq n_2$. Calculate t'. To find its significance level, look up the significance levels of t for (n_1-1) and (n_2-1) d.f. Call these values t_1 and t_2. The significance level of t' is, approximately, $(w_1t_1+w_2t_2)/(w_1+w_2)$, where $w_1 = s_1^2/n_1$, $w_2 = s_2^2/n_2$ (Snedecor and Cockran, 1967, p. 115).

The mean and the variance for each efficiency index in each sample is given in Table 4.6. Does the mean for TES for carcass systems vary significantly from the TES for fabricated systems? This can be tested, once the question of the equality of the two respective variances is answered.

A test of the equality of the two variances is simply a test of the null hypothesis that s_1^2 and s_2^2 are from independent random samples from normal populations with the same variance, σ^2. Since there is no prior reason to anticipate inequality of variance, a two tailed F test is used. The test is $F = s_1^2/s_2^2$, where s_1^2 is the

Table 4.6. Mean and variance of TES, PES and EES for retail stores using carcass or fabricated beef handling systems.

Description		Mean	Variance	Variance Test		Mean Test	
				Computed F	Critical $F_{.05}$	Computed t	Critical $t_{.05}$
Carcass	TES	.9719	.000878	51.647	2.89	3.71185	2.159*
Fabricated	TES	.9981	.000017				
Carcass	PES	.9564	.000472	2.348	2.89	4.649	2.042
Fabricated	PES	.9860	.000201				
Carcass	EES	.9292	.000623	2.265	2.89	7.4866	2.042
Fabricated	EES	.9843	.000275				

*t' is used to find this critical t value.

larger mean square. If the computed F is larger than the critical F found in the F table, the null hypothesis is rejected. The computed F and critical F values are given for each pair of variances being compared in Table 4.6. Only in the comparison of technical efficiency, was the null hypothesis rejected.

Now, the differences in means between meat handling systems for each efficiency measure can be tested. The computed t values and the critical t values are also presented in Table 4.6. If the computed t is greater than the critical t value, the null hypothesis, $H_0: \overline{X}_1 = \overline{X}_2$, is rejected. This is the case for each efficiency measure. In each instance, the means between carcass and fabricated meat handling systems are different.

It is also interesting to note, that the mean for stores that use a fabricated beef handling system is uniformly larger than the mean of stores using the carcass system. This is true for technical, pricing and economic efficiency.

However, before accepting these results or before any economic inferences are made, the assumption of neutrality between the production functions should be examined. Since there are more than two inputs, graphic analysis is impractical. However, as discussed above in Chapter II, some indication of neutrality can be obtained from examining the distribution of the TES indices.

The TES ratings are shown in Table 4.1. There are 17 stores which have a TES rating of unity, 11 stores which utilize the fabricated system and 6 which use the carcass system. Two alternatives of interpretation are available. The first, is to simply assume that the frontier production function for the two groups are exactly the same, or secondly, to conclude that the assumption of neutrality does not hold true. A closer examination of the TES ratings for each scale [28/] raises additional doubt that the production functions are being estimated in an unbiased manner. There are only six stores which have a scale of $11,000 meat sales per week. Since there are four constraints in the linear programming model, at least four stores must be rated as 100 percent efficient. This only leaves two stores which can be less than 100 percent efficient. This additional model constraint arises because of a small sample size in each scale. However, theoretically, if fabricated stores are technically more efficient in a neutral manner, the four stores, in the example above, would have had a TES rating of one, and the two remaining stores, which use the carcass system, would have been rated as less than 100 percent efficient.

Therefore, one must conclude that the assumption of neutrality has been violated in the Farrell and Fieldhouse model. This rejection simply implies that the estimate of the frontier surface by the Farrell

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[28/] These ratings are listed by scale in Appendix C.

and Fieldhouse method indicates that one surface may not lie uniformly below the other, or the firms are grouped such that specification error has entered the model. In either case, the specific analysis of relative efficiency measures between the two meat handling methods which is presented above with respect to the Farrell and Fieldhouse model, is inconclusive.

Relative Efficiency--Farrell Method

Before completely abandoning the frontier model, and realizing that some of the inconsistancy may have arisen from the inclusion of scale in the model, this section will address the same question of relative efficiency, but under the added assumption that the production function is linear and homogeneous. The same assumption of neutral production functions for the two meat handling systems is also retained.

The same question remains relevant: Are there any differences between the technical, pricing and economic efficiencies of the two handling systems? Similarly, the methodology used to investigate this question is exactly the same as that presented above with respect to the Farrell and Fieldhouse estimation.

Tables 4.7, 4.8 and 4.9 show the frequencies for each sample group and each level of technical, pricing and economic efficiency, respectively. It is worth noting that the efficient unit isoquant is

Table 4.7. Technical efficiency ratings (TEC) for retail stores using carcass or fabricated beef handling systems.

TEC Rating	Carcass Handling System	Fabricated Handling System	Total Number of Firms (n)
1.000		5	5
.999		1	1
.997		1	1
.996		1	1
.995		1	1
.994		1	1
.992		4	4
.989		2	2
.987		1	1
.983	1		1
.979	1	1	2
.974	1		1
.969	1		1
.965	1		1
.964	1		1
.950	1		1
.934	1		1
.929	1		1
.928	1		1
.926	1		1
.925	1		1
.914	1		1
.908	1		1
Total	14	18	32

Table 4.8. Price efficiency ratings (PEC) for retail stores using carcass or fabricated beef handling systems.

PEC Rating	Carcass Handling System	Fabricated Handling System	Total Number of Firms (n)
1.000		1	1
.994		1	1
.987	1		1
.986		1	1
.983	1		1
.981		1	1
.972	1		1
.971		1	1
.969		1	1
.968	1		1
.967		1	1
.965	1		1
.964	1	1	2
.963		1	1
.961		2	2
.960		1	1
.957		2	2
.953		2	2
.949	1		1
.943	2		2
.938	1		1
.935	1	1	2
.934	3		3
.926		1	1
Total	14	18	32

Table 4.9. Economic efficiency ratings (EEC) for retail stores using carcass or fabricated beef handling systems.

EEC Rating	Carcass Handling System	Fabricated Handling System	Total Number of Firms (n)
1.000		1	1
.994		1	1
.982		1	1
.980		1	1
.971	1		1
.967		1	1
.964		2	2
.963		1	1
.960		1	1
.957	1		1
.951		1	1
.949		1	1
.947		1	1
.946		2	2
.944		1	1
.941		1	1
.935		1	1
.933	1		1
.923	1		1
.918		1	1
.917	1		1
.909	1		1
.901	1		1
.896	1		1
.888	1		1
.881	1		1
.873	1		1
.872	1		1
.865	1		1
.848	1		1
Total	14	18	32

defined by five firms, each of which use the fabricated system of handling beef. This does not confirm that the production functions are neutral to each other, but fails to refute the neutrality assumption. Since no other method of testing this assumption is known by the author, the remainder of this section will assume neutral production functions for the two meat handling systems.

Most of the n cells have only one observed sample store, and the grouping method suggested by Yamane (1964) and discussed earlier, will also be used here. The groupings for each efficiency measure is shown in Table 4.10. Using the grouped efficiency ratings to establish the probability distribution of the hypothetical population, a null hypothesis can be stated: Both groups have the same probability distribution of the population.

The Chi-square test statistics for this null hypothesis with respect to technical, pricing and economic efficiency are shown in Table 4.11. The computed test statistic, μ, is greater than the critical Chi-square value for technical efficiency at the 5 percent level of significance, while economic efficiency is significantly different at the 10 percent level. The is, the null hypothesis that both groups of stores come from the same population is rejected for relative technical and economic efficiency. On the other hand, the null hypothesis has failed to be rejected for pricing efficiency.

Table 4.10. Frequency distributions for technical, pricing and economic efficiency for grouped ratings.

Grouped Efficiency Ratings	Total Number of Firms
Technical Efficiency	
1.000	5
.999 to .989	11
.987 to .950	9
.934 to .908	7
Total	32
Pricing Efficiency	
1.000 to .981	6
.972 to .960	12
.957 to .926	14
Total	32
Economic Efficiency	
1.000 to .980	4
.971 to .957	7
.951 to .941	7
.935 to .901	7
.896 to .848	7
Total	32

Table 4.11. Chi-square test of homogeneity for retail stores with carcass or fabricated beef handling systems.

Efficiency Measure	μ*	χ^2 **	χ^2 ***
TEC	25.6785	$7.81_{(3,.05)}$	$6.25_{(3,.10)}$
PEC	1.81415	$5.99_{(2,.05)}$	$4.61_{(2,.10)}$
EEC	8.9206	$9.49_{(4,.05)}$	$7.78_{(4,.10)}$

$$* \mu = \sum_r \sum_s \frac{(\text{observed} - \text{expected})^2}{\text{expected}} .$$

** This is the χ^2 value for (n) degrees of freedom and a probability level of α = 5 percent.

*** This is the χ^2 value for (n) degrees of freedom and a probablity level of α = 10 percent.

Following the same statistical procedures established in comparing carcass and fabricated systems with the Farrell and Fieldhouse approach, the equality of variance and means will be tested. The mean and variance of technical, pricing and economic efficiency for each group of retail stores are given in Table 4. 12.

The equality of two variances can be tested using $F = s_1^2/s_2^2$, where s_1^2 is the larger mean square. If the computed F is larger than the critical F, the null hypothesis that the two variances are equal, is rejected. The computed and critical F values for technical, pricing and economic efficiency between the two groups are shown in Table 4. 12. The variance between the groups was significantly different with respect to technical and economic efficiency. The variance of pricing efficiency was the same for carcass and fabricated stores.

Table 4. 12 also contains the test statistics needed to compare the difference in means between the two groups of firms. If the computed t is greater than the critical t value, the null hypothesis, $\bar{X}_1 = \bar{X}_2$, is rejected. The test for the difference in means of technical and economic efficiency indicates that the means are significantly different for both measures of relative efficiency. However, the mean value of relative pricing efficiency for stores that use the carcass system are not significantly different from the mean price efficiency of stores that employ the fabricated beef handling system.

Table 4.12. Mean and variance of technical, pricing and economic efficiency for retail stores using carcass or fabricated beef handling systems.

Description		Mean	Variance	Variance Test: Computed F	Variance Test: Critical $F_{.05}$	Mean Test: Computed t	Mean Test: Critical $t_{.05}$
Carcass	TEC	.946	.0007	13.497	2.89	7.385	2.156*
Fabricated	TEC	.993	.00005				
Carcass	PEC	.954	.0004	1.217	2.89	1.247	2.042
Fabricated	PEC	.961	.0003				
Carcass	EEC	.902	.0012	3.379	2.89	5.460	2.149*
Fabricated	EEC	.957	.0004				

* t' is used to find this critical t value.

Some Remarks About the Model

In Chapter II, a question was raised concerning a bias in the measurement of technical efficiency that may arise because of a firm falling into an unbounded cone in the linear programming model. Bressler (1967) stated that his empirical studies suggested that a surprisingly large proportion of observations suffer from this bias. Of the 32 firms included in this analysis, 23 firms fell into an unbounded cone. It is difficult to know if this is a "surprisingly large number", or not. But a question that may be of more concern is, how are these 23 firms distributed among the two groups under investigation? Thirteen of the 23 firms were stores which use the carcass system while the remaining 10 were stores utilizing the fabricated system. The degree of bias is not known, but based upon this observation, it would seem unlikely that these biased estimates of technical efficiency have seriously affected any hypothesis tested in this model.

However, interpretation of the meaning of the indices of technical and pricing efficiency of these 23 firms is worth exploring. As a result of the bias, the technical efficiency of each of these firms was overestimated, while each of the corresponding price efficiencies was underestimated. An examination of these 23 firms shows that the bias is generally associated with the variable input, labor. But, how should this bias be interpreted?

Assume for the moment a two-factor Leontief-type world, with the two factors being meat and labor. This can be seen more easily with the aid of Figure 4. 1. In addition, it appears from observing the data in this study that one might expect an isoquant similar to that shown in Figure 4. 1, where meat and labor are used in relatively fixed proportions. If this is the case, then how would the efficiencies associated with observation, X_4, be interpreted? First of all, the economic efficiency index is not affected by this bias, and can be interpreted in its usual manner. But, the linear programming model would indicate that X_4 and X_1 have exactly the same technical efficiency index, while it is obvious that X_4 uses $(OL_2\text{-}OL_1)$ more labor than X_1, for the same unit of output. Now, by further assuming that the relative price ratio, M_0M_1, is the same for firms, X_1 and X_4, the price efficiency indices should be unity for both firms. But, this will not be the case. The bias that affected the technical efficiency, also affects the price efficiency associated with firm X_4. In fact, the price efficiency of X_4 will be underestimated by exactly the same amount that the technical efficiency of X_4 was overestimated.

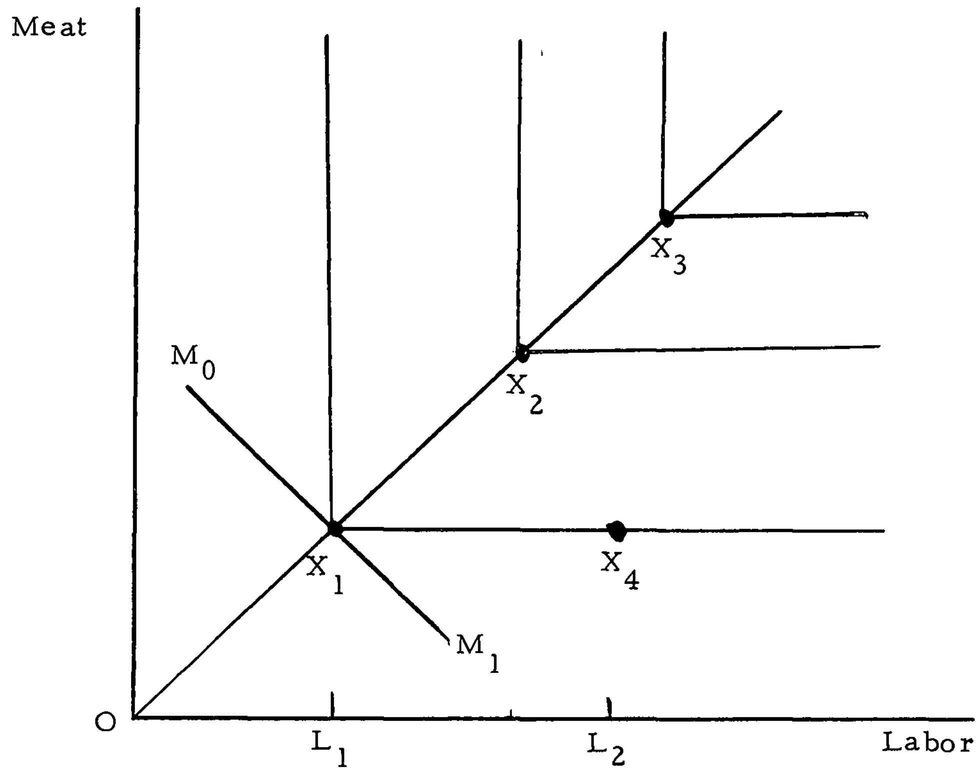

Figure 4. 1. Biased estimates of technical and pricing efficiency.

Does this mean that the technical and pricing efficiencies do not have any meanings? No, each index still has meaning, but the reader should simply be aware of the new dimensions that now surrounds each measure of efficiency. For example, this phenomenon may have occurred simply because labor is a rather "lumpy" input. That is, due to institutional constraints such as labor contracts, or the fact that a meat cutter is hired for 40 hours per week, but is really only needed to cut meat 30 hours, labor comes in a rather discrete unit and can not be purchased in smaller lots. On the other hand, meat can be purchased in much smaller units. Therefore, in a technical sense, the labor associated with firm X_4 may be viewed in a different light than the labor associated with X_1. The amount of labor associated with preparing and selling each pound of meat may have been exactly the same in each firm, and thus, each firm should have the same technical efficiency. But, pricing efficiency has also taken on new dimensions, and no longer simply measures the relative prices of the inputs. The imputed price due to the non-market constraints are now included in the measurement of price efficiency. This example, is simply that, an example, and does not explain the extent of the bias for each of the 23 firms. However, the important fact to recognize, is that the measurement of technical and pricing efficiency is not as pure as presented in the theoretical section of this study, but each is still a useful tool of analysis.

Summary

In summary, two alternative frontier models were introduced in an attempt to measure relative technical, pricing and economic efficiency between retail stores which use the carcass beef handling system and stores which employ a fabricated handling system. The validity of testing relative efficiency in both models is based upon the assumption that the production functions for alternative techniques are exactly the same, or vary in a neutral fashion if one technique is technically more efficient than another. Examination of the distribution of the technical efficiency indices associated with the Farrell and Fieldhouse model, which considers scale effects, indicates that the null hypothesis of neutral production functions between the two production techniques is rejected. Therefore, this model is not adequate to measure relative efficiency.

By placing a more restrictive assumption on the frontier estimation procedure, that of a linear homogeneous production function, the Farrell model is used to measure relative efficiency. Examination of the technical efficiency indices associated with this model, fails to reject the null hypothesis of neutral production functions. Therefore, the Farrell model is used to address the question: Are there any differences between the technical, pricing and economic efficiencies of the two handling systems?

Tests of the null hypothesis that both groups of stores come from the same population is rejected for relative technical and economic efficiency. However, the same null hypothesis has failed to be rejected for relative pricing efficiency. This indicates that the means and, or the variance of the two groups are not the same with respect to technical and economic efficiency. But how do they differ? Variance and mean tests indicate that each of the statistical measures are significantly different between groups for both technical and economic efficiency.

However, the ultimate goal is to determine the relative efficiencies. That is a test of equal means between the two groups of retail stores for each efficiency measure. The mean efficiency associated with stores using fabricated beef handling systems is significantly larger than the mean efficiency of stores with the carcass handling system with respect to relative technical and economic efficiency. On the other hand, there appears to be no statistical difference in the mean of relative pricing efficiency between the two groups of stores.

Estimates of Relative Efficiency--A Profit Model

Introduction

This section will utilize the UOP profit model, to compare relative economic efficiency of groups of firms with varying degrees of technical and pricing efficiency. Conforming to previous definitions, economic efficiency can be decomposed into its two components, technical and price efficiency. A firm is more technically efficient than other firms, if it consistantly produces larger quantities of output from the same quantities of measurable inputs. On the other hand, a firm is said to be price efficient if it maximizes profits. Differences in economic efficiency between groups of firms may be caused by differences in technical and, or price efficiency.

To compare the relative economic efficiency of groups of firms, the actual profit functions of the groups of firms, at given output and input prices and levels of fixed inputs, are computed. The firms with the higher profits within the given range of output and input prices is the more economic efficient group of firms. The derived input demand equations for the variable inputs, meat and labor, are used to estimate technical and pricing efficiency.

The model used in this section was developed by Yotopoulos and Lau (1973), and utilizes the Cobb-Douglas functional form. This model was discussed in earlier chapters, and, therefore, will not be reexamined here. One may recall that the general form of the estimating equations which will be used in this section, were shown in Equations (3.14) and (3.15). Four groups of retail stores, medium and large stores which use the carcass meat handling system and medium and large stores that utilize the fabricated beef system, emerge as the relevant groups for comparison. A set of hypotheses associated with the measures of efficiency, and a test of the degree of returns to scale, will be tested.

Ordinary Least Square Estimates of the Parameters for the UOP Profit and Input Demand Functions

Joint estimation of the UOP profit and input demand equations for the variable inputs, meat and labor, is accomplished by applying the ordinary least square procedure to Equations (3.14) and (3.15). For the specific variables in this study, Equation (3.14) takes the form

$$\ln \pi_a^i = A_*^{MC} + \beta_1 D_1 + \beta_2 D_2 + \beta_3 D_3 + \alpha_1^* \ln c_1 + \alpha_2^* \ln c_2 + \beta_1^* \ln Z_1 + \ln e \qquad (4.1)$$

where:

π_a^i = actual UOP profit for firm i

A_*^{MC} = measure of economic efficiency for medium size stores using the carcass beef meat handling system

D_1 = dummy variable, taking the value of one for large size stores, and zero for medium size stores

D_2 = dummy variable, taking the value of one for retail stores using the fabricated system, and zero for stores with carcass beef handling systems

D_3 = dummy variable, taking the value of one for large retail stores using the fabricated meat handling system, and zero otherwise.

c_1 = normalized aggregate wholesale price for meat

c_2 = normalized wage rate

Z_1 = service flow of capital

e = error term, $\sim N(0, \sigma^2)$

The ordinary least square estimates of the parameters in Equation (4. 1) are shown in Table 4. 13. In addition, the estimates of the derived demand functions for meat and labor are also shown in Table 4. 13.

The specific equations for the derived demand functions, following the general form of Equation (3. 15) are

$$\frac{-c_j^i X_j^i}{\pi_a^i} = \alpha_j^* MC + \beta_1^* D_1 + \beta_2^* D_2 + \beta_3^* D_3 \qquad (4.2)$$

where

X_j^i = the quantity of variable inputs used by firm i, and when

j = 1: pounds of wholesale meat

j = 2: man-hours of labor.

and the remaining variables, c_j^i, π_a^i and the dummies, D_1, D_2 and D_3, follow the same description as those explained above in Equation (4. 1).

One criterion of interest with respect to the specification of each of the models, is the significance of β_3, the coefficient for dummy variable D_3. If β_3 is significant, then the total sample of retail stores should be grouped into four categories, medium and large stores that use the carcass handling system, and medium and large stores that utilize the fabricated beef handling system. The

Table 4.13. Joint estimation of Cobb-Douglas profit function and input demand functions.

Parameter	Single Equation Ordinary Least Squares[a]		Entering F Value	Critical F Value
UOP profit function				
$\ln A_*^{MC}$	4.7417	(6.85759)		
β_1	1.2975	(.2676)	13.8001	4.21
β_2	.5209	(.4433)	.0458	4.22
β_3	- .95004	(.32168)	8.7222	4.24
α_1^*	-4.3432	(4.198)		
α_2^*	-4.011	(2.9725)		
β_1^*	1.117	(.583)		
R^2	.827			
Input demand functions				
Meat			12.695	2.95
α_{meat}^{*MC}	-19.787	(2.0125)		
$\beta_{1\ meat}$	12.338	(2.8462)		
$\beta_{2\ meat}$	13.994	(2.6241)		
$\beta_{3\ meat}$	-11.277	(3.8053)		
R^2	.576			
Labor			12.5393	2.95
α_{labor}^{*MC}	-3.8560	(.4338)		
$\beta_{1\ labor}$	2.8146	(.6135)		
$\beta_{2\ labor}$	2.9005	(.56566)		
$\beta_{3\ labor}$	-2.4725	(.82030)		
R^2	.573			

[a]Numbers in parentheses are assymptotic standard errors.

entering F value for each of the dummy variables is shown in Table 4.13, and is 8.7222 for D_3. The null hypothesis of interest is, $H_0: \beta_3 = 0$, and since the computed F for D_3 is greater than the critical F value, 4.24, the null hypothesis is rejected at the 5 percent level of significance. Hence, one can conclude that the model is adequately specified with respect to this grouping of stores.

However, before continuing with the UOP profit model, and using it for hypothesis testing, two of the basic assumptions of ordinary least squares and multiple regression should be examined, the degree of multicollinearity and homoskedasticity. The presence of any fixed relation between independent variables presents the problem of multicollinearity. If there is a high degree of correlation between the independent variables, unreliable estimates of the correlated coefficients and their variance, may result. A usually accepted tool for detecting the presence of multicollinearity is the inspection of the simple correlations among the independent variables. This procedure is followed, knowing that the simple correlations are only elements of the entire correlation matrix, and in some cases will not warn of a more complex form of multicollinearity. The simple correlation matrix for the variables in Equation (4.1) is presented in Table 4.14, and shows no value greater than -.841. From this, it is assumed that the problem does not seriously bias the model.

Table 4.14. Correlation matrix for variables in the Cobb-Doublas UOP profit function.

		7	8	9	10	11	12	13
Constant	7	1.000	-.055	.615	.809	-.193	-.336	.766
D_1	8		1.000	.509	.180	.310	-.841	-.232
D_2	9			1.000	.494	.147	-.677	.506
D_3	10				1.000	-.244	-.538	.654
c_1	11					1.000	-.161	-.243
c_2	12						1.000	-.173
K_1	13							1.000

Another assumption of the ordinary least square method of estimation is that the variance of the error term is constant for all observations. However, it is possible with cross-sectional data, that even though the observations are drawn at random, they may be from different distributions with zero means, but different variances. This becomes critical when estimates from a heteroskedastic model are used for testing hypotheses. If the incorrect variance is greater than the population variance, the intervals used for testing will be wider than the correct ones, if the incorrect variance is smaller than the population variance, the opposite will be true with respect to the test statistics.

Since it is unknown if the UOP profit model is homoskedastic, or not, it is necessary to test this assumption. Kmenta (1971, p. 267-268) provides a test of the null hypothesis, $\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_m^2$, when several observations of the dependent variable for each specific value of the explanatory variable are available. The test statistic is

$$\hat{\lambda} = \frac{-4.60517 \log m}{1+N}$$

where

$$\log m = \left\{ \sum_i \left[\frac{n_i - 1}{2}\right] \log\left[\frac{n_i s_i^2}{n_i - 1}\right] \right\} - \left\{ \sum_i \left[\frac{n_i - 1}{2}\right] \right\} \left\{ \log\left[\frac{\Sigma n_i s_i^2}{\Sigma (n_i - 1)}\right] \right\}$$

$$N = \frac{1}{3(m-1)} \left\{ \sum_i \left[\frac{1}{n_i}\right] - \frac{1}{n} \right\} \qquad (i = 1, 2, \ldots, m)$$

This test statistic follows the Chi-square distribution with (m-1) degrees of freedom, and the acceptance region for the null hypothesis at the 5 percent level of significance is $\hat{\lambda} \leq \chi^2_{m-1,.05}$.

Following the sample stratification of medium and large retail stores that use the carcass or the fabricated beef handling system, the test statistic becomes

$$\hat{\lambda} = \frac{-4.60517 * -3.01622}{1.053274} = 13.1876$$

The critical χ^2 value for three degrees of freedom and a probability level of 5 percent is 7.31. The critical χ^2 value for a probability of 1 percent is 11.34. Since the value of $\hat{\lambda}$ lies outside the acceptance region, the null hypothesis of homoskedasticity at the 5 and 1 percent level of significance is rejected. The evidence suggests that the variance of the disturbance is not constant.

Another "rule of thumb" method of checking for heteroskedasticity is the plotting of the residuals $(Y_i - \hat{Y}_i)$ against $\hat{Y}$. If the residuals form a horizontal band, one may expect no abnormalty in the model. If the plot shows a systematic expansion or contraction in the arrangement of the residuals, then heteroskedasticity may be suspected. Figure 4.2, shows a plot of the residuals from the Cobb-Douglas UOP profit model, against $\hat{Y}$. It appears that the variance for small values of $\hat{Y}$ are greater than the variance for larger values of $\hat{Y}$. That is, the variance seems to be negatively correlated with the size of the profits.

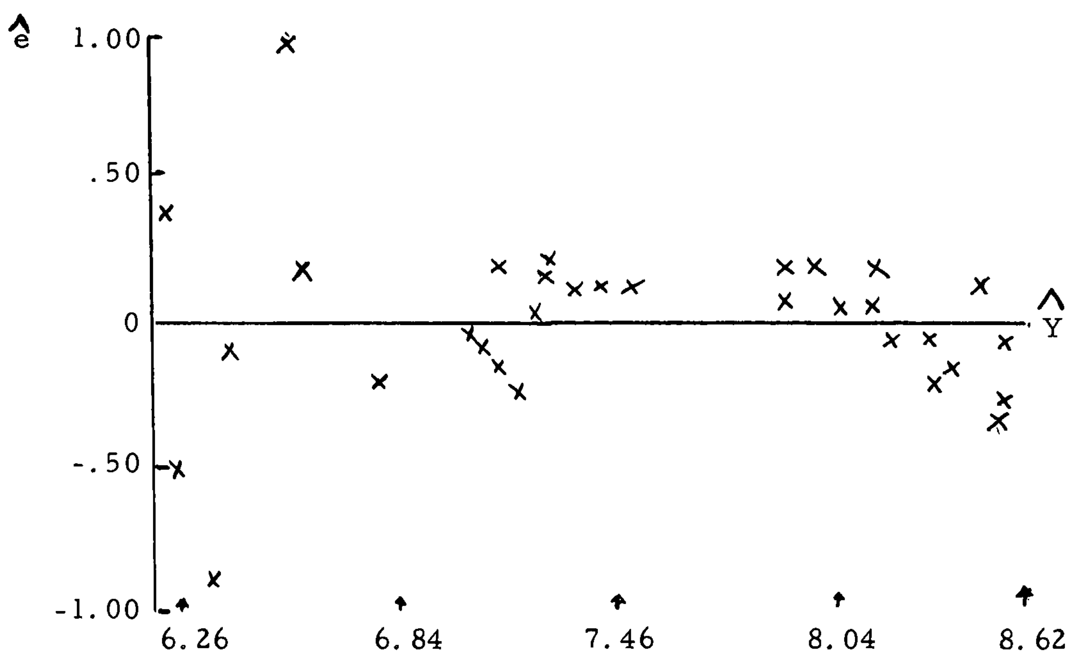

Figure 4.2. Plot of the residuals from the Cobb-Douglas UOP profit model, against $\hat{Y}$.

It should be noted that the statistical test and the plot are only indicators of heteroskedasticity, and do not prove or disprove the assumptions of the model. The grouping for the statistical test is arbitrary, and a different grouping may give different results. For example, although the residuals appear heteroskedastic with respect to size, they appear homoskedastic with respect to the system. The conclusions reached from a plot are only valid when there are a reasonably large number of observations. However, it appears that some correctional procedures should be explored in an attempt to reduce any heteroskedasticity that may exist.

A continuous variable, retail sales of the meat department, was used in the frontier model as a proxy for scale, but has been introduced into the Cobb-Douglas UOP profit model only as a dummy variable. Since the variance is small for large firms, and sales are greater for large firms compared to small firms, the continuous variable, sales, multiplied by each of the variables in Equation (4.1), may yield a weighted equation that will be homoskedastic. The equation becomes

$$\ln \pi_a S = S + \beta_1 D_1 S + \beta_2 D_2 S + \beta_3 D_3 S + \alpha_1^* \ln c_1 S + \alpha_2^* \ln c_2 S + \beta_1^* \ln Z_1 S + \ln e \qquad (4.3)$$

where, S = continuous variable, sales, and all the other variables are exactly the same as those described in Equation (4.1). The single equation ordinary least square estimates of the parameters in Equation (4.3) are shown in Table 4.15. Since the equation has been forced through the origin, no standard error values are available from the computer algorithm used to compute these regressions.

Table 4.15. Estimation of weighted Cobb-Douglas UOP profit function.

Parameter	Single Equation Ordinary Least Squares
$\ln A_*^{MC}$	6.2925
β_1	.0000469
β_2	-.0000681
β_3	-.0000818
α_1^*	-2.4294
α_2^*	-2.6843
β_1^*	.57942
R^2	.967

A plot of the residuals against $\hat{Y}$ for Equation (4.3) is shown in Figure 4.3. It appears that the residuals have a tendency to become a horizontal band, which when compared to Figure 4.2, shows that there may be an indication that this model has less abnormality concerning the constancy of the variance. If this observation is true,

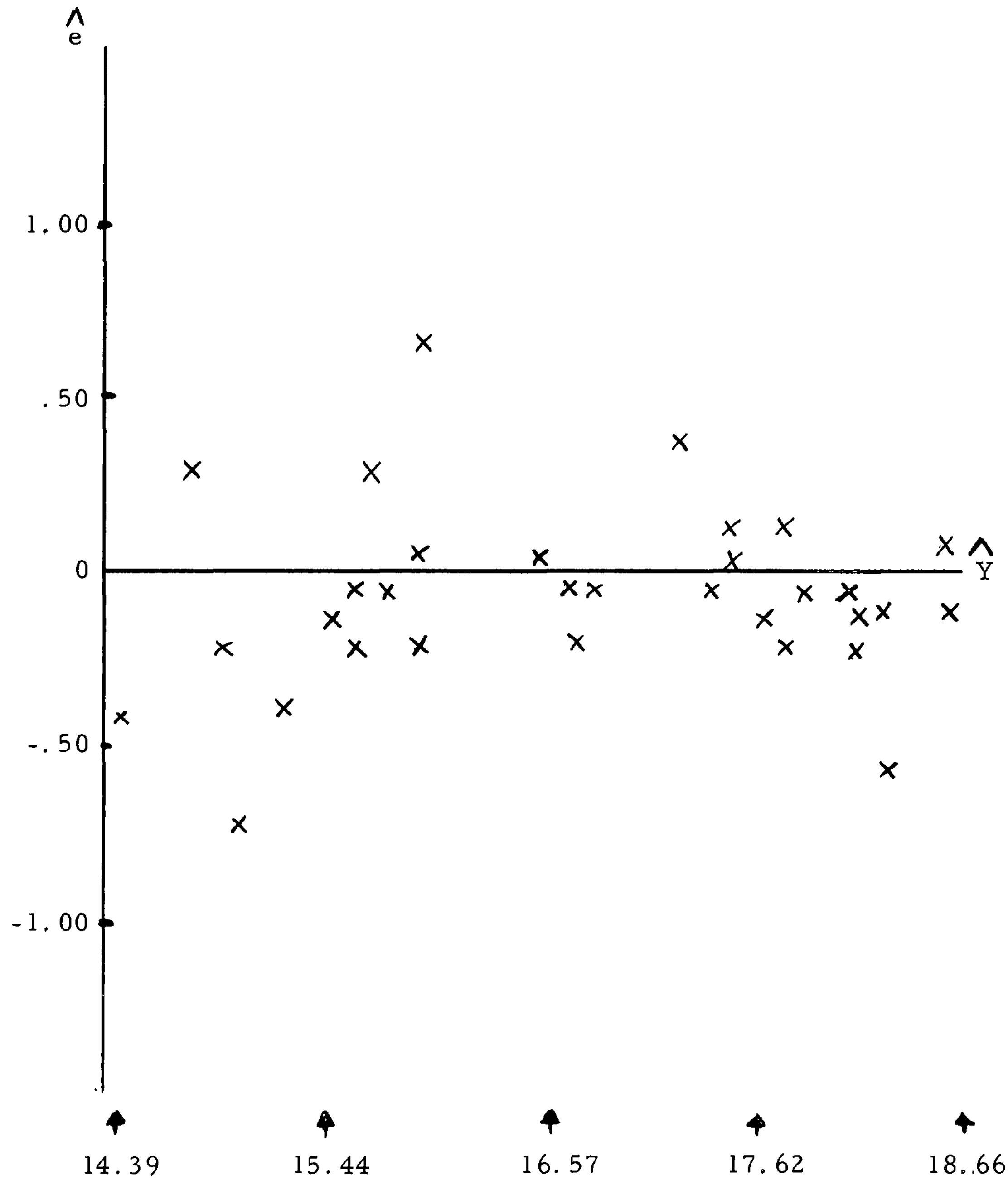

Figure 4.3. Plot of the residuals from the weighted Cobb-Douglas profit function against $\hat{Y}$.

the test of homoskedasticity suggested by Kmenta can be computed for this model, and should provide some indication of the reduction in heteroskedasticity. The test statistic is

$$\hat{\lambda} = \frac{-4.60517 \times -1.6926}{1.053274} = 7.40046$$

and the critical χ^2 value for 3 degrees of freedom and a 5 percent probability level is 7.81. Therefore, it appears that one should fail to reject the null hypothesis of homoskedasticity for the weighted model.

However, before the weighted model is fully accepted, a quick look at the correlation matrix for the model, Table 4.16, shows that a high degree of multicollinearity has been introduced into the model. Several of the variables have a correlation coefficient greater than .95. If the regression coefficients obtained from Equation (4.1) are compared to those from Equation (4.3), one can observe that the coefficients for meat, labor, and capital have all become smaller, indicating that much of their effect may have been absorbed by the size variable. This high multicollinearity appears to have significantly altered the regression coefficients, and has introduced an unreliability to each of them, that can not be ignored.

What can be done to correct for this threat to the model? Not much, because all of the prior information has been used in specifying the model, and no other information is available from other samples. The trade-off between a model that has some indication of heteroskedasticity must be weighed against a model with multicollinearity. That is, the choice is to choose the least of two evils.

Table 4.16. Correlation matrix for variables in the weighted Cobb-Douglas UOP profit function.

		15	16	17	18	19	20	21	22
D_1	15	1.000	.353	.610	.874	.920	.915	.914	.919
D_2	16		1.000	.880	.429	.376	.256	.326	.364
D_3	17			1.000	.542	.565	.486	.564	.554
$\pi_a S$	18				1.000	.947	.922	.922	.949
$c_1 S$	19					1.000	.989	.973	.999
$c_2 S$	20						1.000	.972	.991
$K_1 S$	21							1.000	.974
S	22								1.000

One factor that should be considered at this point is the purpose of the model. That is, is the model being used to predict a value for the dependent value, Y, or, is the primary purpose of the model, the estimation of the parameters for the independent variables? If the sole purpose is to predict, and the researcher feels that a model with high multicollinearity is the best tool to use, then the answer is simple, use it. But, if the purpose of the model is the estimation of the parameters for the independent variables, then a model with high multicollinearity should not be used. What does that leave? A model that has some heteroskedastic tendencies, which may raise some question as to the validity of the tests concerning confidence intervals, but a model from which one should expect reasonably reliable estimates of the regression coefficients. Since the purpose of the model in this study is not to predict, but to estimate the parameters, Equation (4.1) will be used.

Now that a decision has been made concerning the estimation of the profit function, the estimates of the input demand functions for meat and labor, shown in Table 4.13, do not need adjustment, and can be used as reported. Since each of the independent variables in the input demand functions is a dummy variable, the mean value for the demand function of each variable input for medium and large stores with carcass or fabricated beef handling systems can be computed from the estimates reported in Table 4.13. The mean value for meat and labor for each group of stores is shown in Table 4.17

Testing the Constancy of a Subset of Regression Coefficients

A maintained hypothesis in deriving relative economic efficiency from the UOP profit function is that the production function is identical up to a neutral efficiency parameter in a meat department of medium and large retail stores that use the carcass or fabricated

Table 4.17. Estimates of the mean of the input demand functions for meat and labor for medium and large stores with carcass or fabricated beef handling systems.[a]

Parameter		Mean
Meat		
α^{*MC}_{meat}	$= \alpha^{*MC}_{meat}$	-19.787
$\alpha^{*MC}_{meat} + \beta_1$	$= \alpha^{*LC}_{meat}$	- 7.447
$\alpha^{*MC}_{meat} + \beta_2$	$= \alpha^{*MF}_{meat}$	- 5.793
$\alpha^{*MC}_{meat} + \beta_1 + \beta_2 + \beta_3$	$= \alpha^{*LF}_{meat}$	- 4.732
Labor		
α^{*MC}_{labor}	$= \alpha^{*MC}_{labor}$	- 3.8560
$\alpha^{*MC}_{labor} + \beta_1$	$= \alpha^{*LC}_{labor}$	- 1.0414
$\alpha^{*MC}_{labor} + \beta_2$	$= \alpha^{*MF}_{labor}$	- .9550
$\alpha^{*MC}_{labor} + \beta_1 + \beta_2 + \beta_3$	$= \alpha^{*LF}_{labor}$	- .6134

[a]The data in this table originates in Table 4.13.

meat handling system. This implies that the coefficients corresponding to $\ln c_1$, $\ln c_2$, and $\ln K$ are identical for each type of retail store. The validity of this hypothesis can be tested by examining the constancy of the regression coefficients for meat, labor, and capital. Huang (1970, p. 112-116) sets forth a testing procedure which is straightforward and utilizes the F test statistic, where

$$F = \frac{Q_3/L}{Q_2/(n-2m-2L)} .$$

Q_3 is the restricted sum of squares that has been set forth by the hypothesis being tested, less the unrestricted sum of squares. Q_2 is simply the unrestricted sum of squares.

This F statistic is based on the two separate values for the sum of squares of the residuals under the null and under the alternative hypothesis. The alternative hypothesis implies no restrictions on the parameters. Therefore, when ordinary least squares is used for estimation, the residual sum of squares under the alternative hypothesis is the minimum value of sum of squares. However, when the regression is estimated under the assumption that the null hypothesis is true, the residual sum of squares will be larger. This occurs because of the restrictions imposed by the null hypothesis. This increase in the residual sum of squares provides the basis for the test. That is, the test is to see whether the increase in the residual sum of squares, due to the restriction of the null hypothesis, is significantly different from zero. It may be important to note that this test will be used several times in succeeding sections.

The parameters for this test are obtained by simply computing single equation least square estimates of meat, labor, and capital for each of the four groups of stores in the study. That is, the following equation is computed for each sample subset:

$$\ln \pi_a = \beta_0 + \alpha_1^{**} \ln c_1 + \alpha_2^{**} \ln c_2 + \beta_1^{**} \ln K + \ln e \qquad (4.4)$$

The residual sum of squares for each group of stores, estimated by Equation (4.4), are shown in Table 4.18. In addition, the residual sum of squares for Equation (4.1), where the groups have been pooled, is also shown in Table 4.18.

Table 4.18. Residual sum of squares for single equation least square estimates of medium and large stores using carcass or fabricated beef handling systems.

Equation	Residual Sum of Squares
Medium carcass	2.2956
Large carcass	.06848
Medium fabricated	.12566
Large fabricated	.35798
Pooled Equation (4.1)	3.9575

The F test is simply,

$$F = \frac{[SSR_p-(SSR_1+SSR_2+SSR_3+SSR_4)]/L}{(SSR_1+SSR_2+SSR_3+SSR_4)/n-2m-2L}$$

and in this particular case, takes the specific value

$$F = \frac{[3.9575-(2.2956+.06848+.12566+.35798)]/9}{(2.84772)/16}$$

$$F = .6928$$

The critical F value for 9 and 16 degrees of freedom and a 5 percent level of significance is 2.54. Since .6928 is less than the critical F value, 2.54, the null hypothesis that the coefficients for $\ln c_1$, $\ln c_2$, and $\ln K$ remain the same for each type of retail store, is not rejected.

Hypotheses Testing

In this section, six hypotheses are tested on the data. The first five deal with specific hypotheses about relative economic and price efficiency, while the last hypothesis deals with returns to scale.

The first hypothesis that can be investigated from the UOP profit framework is that the relative economic efficiencies for medium and large retail stores which use the fabricated or carcass beef handling system, are equal. This implies that $A_*^{MC} = A_*^{LC} = A_*^{MF} = A_*^{LF}$, or that the change in the intercept values associated with each group of retail stores does not significantly differ from zero. That is, the null hypothesis is, H_0: $\beta_1 = \beta_2 = \beta_3 = 0$. It is important to note that this test does not measure the relative efficiency of technical or pricing efficiency among the firms. Stores may be equally economic efficient, but have different technical and pricing efficiencies.

The test of the null hypothesis that there is no difference in the relative economic efficiency among groups of retail stores can be tested by considering the residual sum of square of two regressions, one containing the dummy variables associated with each of the groups of retail stores, and the second without the dummy variables. The relevant statistical test is the F-test that has been previously described. The computed F-value is 8.6826, while the critical F-value, for 3 and 25 degrees of freedom and a 5 percent level of significance, is 2.99. Since the computed F-value is greater than the critical, the null hypothesis of equal relative economic efficiency across the four groups of retail stores, is rejected. This is an interesting result, but which group of firms are significantly more efficient?

This question can be explored by examining the intercept values shown in Table 4.19, and their variance. It appears that large stores employing the carcass handling system are the most relative efficient, while medium sized stores which use the carcass system are the least relative efficient. But, is there a significant difference between large stores that use the carcass system and large stores that utilize the fabricated handling system? This can be tested using the t-test, and testing the null hypothesis, $A_{*}^{LC} = A_{*}^{LF}$. This hypothesis can be restated as $H_0: \beta_0 + \beta_1 - (\beta_0 + \beta_1 + \beta_2 + \beta_3) = 0$, or $H_0: -\beta_2 - \beta_3 = 0$. The t statistic is

$$t = \frac{.42914}{.407175} = 1.0539.$$

The critical t value for 25 degrees of freedom and a significance level of 5 percent is 2.06. Since the computed t is less than the critical value, the null hypothesis is not rejected, and one may conclude that there is no significant difference between the relative economic efficiency of large retail stores using the two alternative beef handling systems. A question, similar to that asked above, can be asked for each pair of groups in the sample. Table 4.20, shows the null hypothesis for each pair of retail groups and the corresponding computed and critical t values. Comparison of the critical and computed values show that the null hypothesis can be rejected for two groups, medium and large sized stores that use the carcass handling system, and medium carcass and large fabricated stores. These results indicate that there are no significant general differences between groups of retail stores with respect to meat handling systems,

Table 4.19. Intercept values, ($\ln A^i_*$) for medium and large stores using carcass or fabricated beef handling systems.[b]

System	Intercept Value ($\ln A^i_*$)
Medium carcass	4.7417
Large carcass	6.0392
Medium fabricated	5.2626
Large fabricated	5.6101

Table 4.20. Test of equal relative economic efficiency between paired groups of retail stores.[b]

Null Hypothesis for Paired Groups[a]	Computed t-Value	Critical t-Value α = .05
$A^{MC}_* = A^{LC}_*$	4.849*	2.06
$A^{MF}_* = A^{LF}_*$	1.100	2.06
$A^{MC}_* = A^{MF}_*$	1.175	2.06
$A^{LC}_* = A^{LF}_*$	1.054	2.06
$A^{MC}_* = A^{LF}_*$	1.858**	2.06
$A^{MF}_* = A^{LC}_*$	1.657	2.06

[a]MC = medium carcass.
LC = large carcass.
MF = medium fabricated.
LF = large fabricated.

*Significantly different at the 5 percent level.

**Significantly different at the 10 percent level.

[b]The data in this table originates in Table 4.13.

but show that the difference arises between medium sized stores using the carcass beef handling system and large stores, irrespective to their meat handling system.

The third hypothesis that can be tested is that medium and large stores with carcass or fabricated handling systems, have the same relative price efficiency for each variable input, meat and labor. Equation (4.2) was used to estimate the input demand functions for each input, and the estimated parameters were reported in Table 4.13. The relevant null hypothesis for each input demand equation is

$$H_0: \beta_1 = \beta_2 = \beta_3 = 0 .$$

Since these three parameters are the only variables estimated in each equation, the appropriate test statistic is simply the test of the hypothesis that none of the explanatory variables has an influence on the mean of the dependent variable. The F statistic, where

$$F_{k-1, n-k} = \frac{SSR/(k-1)}{SSE/(n-k)}$$

can be used to test this null hypothesis. The computed F value for the input demand function for meat is 12.695, and 12.539 for labor. The critical F value for 3 and 28 degrees of freedom and a 5 percent significance level is 2.95. Hence, with respect to both meat and labor, the null hypothesis, $H_0: \beta_1 = \beta_2 = \beta_3 = 0$, is rejected, and one may conclude that the relative price efficiency for meat and labor varies across the groups of firms.

Just as in the case of economic efficiency, the more specific test of which groups of firms are significantly different with respect to price efficiency, becomes important. That is, which groups of firms are significantly different with respect to their relative price efficiency of meat and labor? This can be tested, using the t test, and testing the null hypothesis, $H_0: \alpha_j^{*i} = \alpha_j^{*i*}$, where $i \neq i*$. This test of equal relative price efficiency for meat and labor for each pair of groups of retail stores in the sample is tabulated in Table 4.21. With respect to both meat and labor, medium sized retail stores that use the carcass beef handling system are significantly different from all other groups. In addition, there is no significant difference between any of the remaining groups.

With a model of joint estimation of the UOP profit and the input demand functions, one may also investigate the absolute price efficiency hypothesis, that each group of firms has maximized profits subject to given prices. Yotopoulos and Lau (1973) show that for perfect profit maximization in the ith group of firms,

$$k_{\ell}^{i} = 1 \qquad \ell = 1, \ldots, m$$

and

$$k_{*}^{i} = 1 \ .$$

Table 4.21. Test of equal relative price efficiency for meat and labor between paired groups of retail stores.[b]

Null Hypothesis for Paired Groups[a]	Computed t-Value	Critical t-Value $\alpha = .05$
<u>Meat</u>		
$\alpha_1^{*MC} = \alpha_1^{*LC}$	4.335*	2.06
$\alpha_1^{*MC} = \alpha_1^{*MF}$	5.333*	2.06
$\alpha_1^{*MC} = \alpha_1^{*LF}$	5.873*	2.06
$\alpha_1^{*LC} = \alpha_1^{*MF}$	.501	2.06
$\alpha_1^{*LC} = \alpha_1^{*LF}$	.539	2.06
$\alpha_1^{*MF} = \alpha_1^{*LF}$	.192	2.06
<u>Labor</u>		
$\alpha_2^{*MC} = \alpha_2^{*LC}$	4.587*	2.06
$\alpha_2^{*MC} = \alpha_2^{*MF}$	5.127*	2.06
$\alpha_2^{*MC} = \alpha_2^{*LF}$	5.483*	2.06
$\alpha_2^{*LC} = \alpha_2^{*MF}$	.121	2.06
$\alpha_2^{*LC} = \alpha_2^{*LF}$	.374	2.06
$\alpha_2^{*MF} = \alpha_2^{*LF}$	.287	2.06

[a]MC = medium carcass.
LC = large carcass.
MF = medium fabricated.
LF = large fabricated.

*Significantly different at the 5 percent level.

[b]The data in this table originates in Table 4.13.

In addition, Yotopoulos and Lau show that a necessary and sufficient statistical test of the null hypothesis of profit maximization, simply becomes, $H_0: \alpha_\ell^{*i} = \alpha_\ell^{*}$, $\ell = 1, \ldots, m$. It is important to note, that α_ℓ^{*i} and α_i^{*} are parameters derived from separate equations, the input demand functions and the UOP profit function, respectively. But, how can two parameters from two different equations be compared? Combining the two equations into one, the test procedure is simply a special case of an F test that was discussed earlier. That is, the test procedure is based on the residual sum of squares under the null and the alternative hypotheses.

The UOP profit and input demand functions can be estimated as one equation by introducing a dummy variable, DE, to distinguish between the two sets of data. Letting DE take a value of one when corresponding to the UOP profit data set, and zero for the input demand set, the combined data sets can be written as one equation

$$Y = \alpha_\ell^{*MC} + \beta_0^{*}DE + \beta_{1\ell}D_1 + \beta_1^{*}(D_1DE) + \beta_{2\ell}D_2 + \beta_2^{*}(D_2DE)$$
$$+ \beta_{3\ell}D_3 + \beta_3^{*}(D_3DE) + \alpha_1^{*}(\ln c_1DE) + \alpha_2^{*}(\ln c_2DE)$$
$$+ \beta_1^{*}(\ln K\ DE) + e \qquad (4.5)$$

where

$$Y = \ln \pi_a^i \text{ for observations in the profit model and}$$

$$-(\frac{c_i X_\ell}{\pi_a^i}) \text{ for observations in the input demand function, } \ell.$$

Estimates from the pooled data are exactly the same as the regression estimates obtained by estimating each of the equations separately. The sum of squares of residuals in Equation (4.5) is equal to the summation of the two sums of squares of residuals from the separate equations. In addition, the degrees of freedom for Equation (4.5) is simply the sum of the degrees of freedom for each separate equation.

The test statistic can be computed by obtaining the residual sum of squares under both the null and the alternative hypothesis. The ordinary least square estimation of Equation (4.5) gives the residual sum of squares under the alternative hypothesis. The restricted residual sum of squares can be obtained by estimating Equation (4.5) with the restrictions implied by the null hypothesis. One may recall that α_ℓ^{*i} is simply the mean value of the dependent variable in the estimated input demand functions. Therefore, α_ℓ^{*i}, corresponding to each group of retail stores, is obtained by some combination of the regression coefficients associated with the dummy variables in the input demand function. For example, α_{meat}^{*i} for large stores that use the carcass beef handling system is

$\alpha^{*MC}_{meat} + \beta_{1\ meat}$. Therefore, the null hypothesis that large stores with carcass systems, maximize profits with respect to the variable input, meat, can be stated as, $H_0: \alpha^{*MC}_{meat} + \beta_{11} = \alpha^*_1$. Given this null hypothesis, what constraints are imposed on Equation (4.4)? Putting everything in terms of β_{11}, one gets $\alpha^*_1 = \alpha^{*MC}_{meat} = \beta_{11}$. Substituting, $\alpha^*_1 - \alpha^{*MC}_{meat}$, into Equation (4.4), the restricted equation becomes

$$Y = \alpha^{*MC}_{meat}(1-D_1) + \beta^*_0 DE + \beta^*_1(D_1 DE) + \beta_{21}D_2 + \beta^*_2(D_2 DE) + \beta_{31}D_3$$

$$+ \beta^*_3(D_3 DE) + \alpha^*_1(\ln c_1 DE + D) + \alpha^*_2(\ln c_2 DE)$$

$$+ \beta^*_1(\ln K\ DE) + e \qquad (4.6)$$

It may be noted that the number of restrictions imposed by the null hypothesis in estimating Equation (4.6) also equals the number of terms deleted, in this case, one. Now, all that is needed is the residual sum of squares for Equation (4.6), and the F test can be computed. Continuing with the example for large retail stores which use the carcass beef handling system, the F test becomes

$$F = \frac{797.925 - 797.838/1}{797.838/53} = .0057 .$$

The critical F value for 1 and 53 degrees of freedom, and a significance level of 5 percent, is 4.02. Since the computed F is less than the critical F value, the null hypothesis has failed to be rejected. Hence, it would appear that large stores which use the carcass system are profit maximizers with respect to the variable input, meat. The computed F values associated with the null hypothesis of profit maximization for each group of retail stores and the variable inputs, meat and labor, are shown in Table 4.22. None of the computed F values in Table 4.22 are greater than the critical F value at the 5 percent level of significance. Therefore, it may appear that all of the groups of firms attempt to maximize profits with respect to both variable inputs, meat and labor.

Table 4.22. F values for profit maximization of variable inputs, meat and labor, for medium and large retail stores that use the carcass or fabricated beef handling systems.

	Computed F-Value*	
Groups of Stores	Meat	Labor
Medium carcass	.1421	.0006
Large carcass	.0057	.2045
Medium fabricated	.0013	.2166
Large fabricated	.0001	.2677

*The critical F value applicable to all groups of stores, for 1 and 53 degrees of freedom and a 5 percent level of significance is 4.02.

However, if one simply looks at the relative difference in the parameters being compared, these results raise suspicions. They simply are not the results that one might expect. One look at the simple correlation matrix for the pooled data, Table 4.23, raises ones suspicions even higher. It appears that in pooling the data, high multicollinearity was introduced into the model. Even though this high multicollinearity did not affect the regression coefficients, the variances of the least square estimators were greatly increased, and as a result, the F tests have given imprecise estimates in the hypothesis tests of profit maximization. This large variance arose because of the small dispersion in the explanatory variables, meat, labor and capital. That is, when the data was pooled, a 3 x 32 set of zeros was introduced into the model, since the input demand functions do not contain the independent variables, meat, labor or capital. This resulted in a large variance and also is reflected in the high correlation coefficients, shown in Table 4.23.

What can be done to correct for this? There appears to be no other manner in which the data can be pooled, or adjusted to correct for this multicollinearity. But, why were the data pooled in the first place? The data were pooled so that the null hypothesis, $H_0: a_\ell^{i*} = a_\ell^{*}$, could be tested. One may recall that these two coefficients are determined in separate equations. And, since these equations are not independent, the equations were pooled so that a covariance term associated with these two coefficients would enter into the estimate of the test statistic. However, this objective was foiled by the multicollinearity. The importance or magnitude of the

Table 4.23. Correlation matrix for variables in the pooled efficiency equation.

		7	8	9	11	12	13	18	19	20	21
D_1	7	1.000	-.055	.615	-.009	-.015	.030	0	.589	-.030	.402
D_2	8		1.000	.509	.015	-.037	-.009	0	-.033	.552	.333
D_3	9			1.000	.007	-.030	.020	0	.362	.281	.655
c_1	11				1.000	-.996	-.997	-.998	-.563	-.608	-.368
c_2	12					1.000	.996	.998	.535	.583	.338
K	13						1.000	.998	.588	.614	.403
DE	18							1.000	.553	.626	.378
(D_1DE)	19								1.000	.310	.683
(D_2DE)	20									1.000	.604
(D_3DE)	21										1.000

covariance term is not obvious from any estimate available in the model, but it seems that some knowledge and at least a "biased estimate" of the hypothesis of profit maximization is worth further exploration.

One avenue of exploration can be persued if the assumption is made that the UOP profit function and the input demand function are independent. This implies that the covariance terms between the coefficients in each of the models is zero. This assumption allows the hypothesis test of profit maximization to simply follow the t test,

$$t = \frac{\alpha_\ell^{*i} - \alpha_\ell^{*}}{\sqrt{\dfrac{n*var(\alpha_\ell^{*i}) + n*var(\alpha_\ell^{*})}{n_1 + n_2 - 2}}}$$

The computed t values associated with the null hypothesis of profit maximization for each group of retail stores and the variable inputs, meat and labor, are shown in Table 4.24. As expected, the results are different from those of the F-test. It now appears that one group of stores, medium carcass, do not maximize profits with respect to meat. It is very important to remind the reader that these observations are based on a test statistic that is known to be biased, and that the degree of bias is not known.

Table 4.24. T values, assuming independence, for profit maximization of variable inputs, meat and labor, for medium and large retail stores that use the carcass or fabricated beef handling system.

Group of Stores	Computed t-Values*	
	Meat	Labor
Medium carcass	4.691	.073
Large carcass	.866	1.384
Medium fabricated	.414	1.428
Large fabricated	.065	1.543

*The critical t value at the 5 percent level of significance is 2.06.

The reader may ask, what conclusions can be made? The answer is, with respect to these two test statistics, absolutely no statistical inference can be made. Neither test can hold its own in a theoretical sense. However, the t test may given the reader some general feel for the outcome of the hypothesis test of profit maximization, assuming the covariance term is small.

The last hypothesis that will be tested with respect to the UOP profit function, is the degree of returns to scale. Again following the procedure set forth by Yotopoulos and Lau, the necessary and sufficient condition for homogeneity of degree k of the underlying production function and for the case of the Cobb-Douglas profit function is

$$\frac{k-1}{k} \sum_{j=1}^{m} \alpha_j^* + \frac{1}{k} \sum_{j=1}^{m} \beta_j^* = 1$$

or

$$\sum_{j=1}^{m} \beta_j^* = k - (k-1) \sum_{j=1}^{m} \alpha_j^* .$$

It was shown earlier that $\sum_{j=1}^{n} \alpha_j^* < 0$, thus for a firm with increasing returns to scale, $k > 1$, the $\sum_{j=1}^{m} \beta_j^* > 1$. If a firm has constant returns to scale and $k = 1$, then $\sum_{j=1}^{m} \beta_j^* = 1$. If $k < 1$, and a firm has decreasing returns to scale, $\sum_{j=1}^{m} \beta_j^* < 1$. Therefore, a relevant hypothesis is that of constant returns to scale in all inputs. For the Cobb-Douglas UOP profit function, this becomes a test of the null hypothesis that $\sum_{j=1}^{m} \beta_j^* = 1$, where β_j^* are the elasticities of the profit function with respect to the fixed factors of productions. In this study the test is simply that $\beta_1^* = 0$, where β_1^* is the elasticity associated with the fixed input, K, the service flow of capital. This test can be carried out by using the t test.

$$t = \frac{\beta_1^* - 1}{\sqrt{\mathrm{var}(\hat{b}_1)}} = \frac{.117}{.583} = .2007 .$$

The critical t value at the 5 percent level of significance is 2.06. Therefore, one can conclude that constant returns to scale prevail.

It is important to note that each of the proceeding tests may be subject to some suspect if a high degree of heteroskedasticity is present in the model. Tests at the beginning of this chapter indicated that some heteroskedasticity is present, but due to the illusive nature of this statistical problem which so often plagues cross-sectional data analysis, the extent to which any one test is affected is unknown.

Additional Estimates

Three additional sets of parameters can be estimated from the UOP profit and input demand functions. Indirect estimates of the production elasticities of meat, labor, and capital can be estimated from the UOP profit function. In addition, technical and price efficiency parameters for meat and labor, associated with each group of retail stores, are estimated.

It was shown earlier in Equations (3.8) and (3.9), that the following relationships existed in the UOP profit function,

$$\alpha_j^* \equiv -\alpha_j(1-\mu)^{-1} < 0 ,$$

where μ is the summation of the profit elasticities associated with the variable inputs, and

$$\beta_j^* \equiv \beta_j(1-\mu)^{-1} > 0 ,$$

where β_j^* is the profit elasticity associated with the fixed inputs. Given these relationships, and the values of the profit elasticities,

α_j^* and β_j^*, one can solve for, α_j and β_j, the indirect estimates of the production elasticities of each of the inputs in the production function. In a general form, and using matrix notation, $AX = b$, one simply needs to solve for X, when

$$A = \begin{bmatrix} (\alpha_1^*-1), \alpha_1^*, & \dots, & \alpha_1^* & , 0 \\ \alpha_2^*, (\alpha_2^*-1), & \dots, & \alpha_2^* & , 0 \\ \vdots \quad \vdots & & \vdots & \vdots \\ \alpha_n^*, \quad \alpha_n^* & , \dots, & (\alpha_n^*-1), & 0 \\ \beta_1^*, \quad \beta_1^* & , \dots, & \beta_1^* & , 1 \end{bmatrix} \qquad X = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_n \\ \beta_1 \end{bmatrix}$$

and

$$b = \begin{bmatrix} \alpha_1^* \\ \alpha_2^* \\ \vdots \\ \alpha_n^* \\ \beta_1^* \end{bmatrix} .$$

The indirect estimates of the production elasticities of meat, labor, and capital, estimated from the UOP profit function, Equation (4.1), are shown in Table 4.25.

It was pointed out earlier that the value of k_j^i and k_*^i, reflect a general systematic rule of behavior concerning profit maximization. That is, if these two values are unity, the firm is following a decision rule that yields profit maximization with respect to each variable

Table 4.25. Indirect estimates of the input elasticities of the production function and the efficiency parameters.

Parameter		Estimate
	Indirect Input Elasticities	
Meat	α_1	.4643
Labor	α_2	.4288
Capital	β_1	.1194
	Efficiency Parameters	
Medium carcass		
Meat	k_1^{MC}	.5782
Labor	k_2^{MC}	2.7408
Technical	A^{MC}	5.7369
Large carcass		
Meat	k_1^{LC}	.5915
Labor	k_2^{LC}	3.9076
Technical	A^{LC}	7.0022
Medium fabricated		
Meat	k_1^{MF}	.6210
Labor	k_2^{MF}	3.4772
Technical	A^{MF}	6.1352
Large fabricated		
Meat	k_1^{LF}	.6226
Labor	k_2^{LF}	4.4356
Technical	A^{LF}	6.9268

input, j. Therefore, the value of k_j^i may be of interest, and can be found by using Equations (3.7) and (3.13). Repeating these two equations:

$$k_*^i \equiv (1-\sum_{j=1}^{n} a_j/k_j^i)(1-\mu)^{-1} \tag{3.7}$$

and

$$\frac{-c_\ell^i X_\ell^i}{\pi_a^i} = (k_\ell^i)^{-1}(k_*^i)^{-1} a_\ell^* \equiv a_\ell^{*i} . \tag{3.13}$$

The objective is to solve them simultaneously to find k_j^i. Substituting Equation (3.7) into Equation (3.13), one gets

$$\sum_{j=1}^{n} n_j\left(\frac{1}{k_j^i}\right) + \frac{1-\mu a_\ell^*}{a_\ell^{*i}}\left(\frac{1}{k_j^i}\right) = 1 \tag{4.7}$$

Putting Equation (4.7) into matrix form,

$$A_1 = \begin{bmatrix} a_1, a_2, \dots, a_n \\ a_1, a_2, \dots, a_n \\ \vdots \quad \vdots \quad \vdots \\ a_1, a_2, \dots, a_n \end{bmatrix} \quad K = \begin{bmatrix} 1/k_1^i \\ 1/k_2^i \\ \vdots \\ 1/k_n^i \end{bmatrix} + A_2 = \begin{bmatrix} \frac{(1-\mu)a_1^*}{a_1^{*i}} & & \\ & \frac{(1-\mu)a_2^*}{a_2^{*i}} & \\ & & \ddots \\ & & & \frac{(1-\mu)a_n^*}{a_n^{*i}} \end{bmatrix}$$

$$K = \begin{bmatrix} 1/k_1^i \\ 1/k_2^i \\ \vdots \\ 1/k_n^i \end{bmatrix} = b = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} .$$

Since the vector K associated with A_1 and A_2 is the same, the matrices A_1 and A_2 can be added so that $A = A_1 + A_2$. Once this has been done, the equation $AK = b$, simply needs to be solved. The values obtained in vector K will be the inverse of k_j^i, and must be inverted to obtain the parameter, k_j^i. These values for meat and labor for each of the four groups of retail stores are tabulated in Table 4.25.

The last parameter to be estimates is, A^i, the technical efficiency parameter associated with the UOP profit function. The constant term, A_*^i, was defined earlier as

$$A_*^i = A^{i(1-\mu)^{-1}} \left(1 - \sum_{j=1}^{n} a_j/k_j^i\right)\left(\pi(k_j^i)^{a_j^*}\right)\left(\pi a_j^{a_j(1-\mu)^{-1}}\right).$$

All of the terms in this equation have been defined, except A^i. Therefore, A^i can be obtained by simply substituting each known parameter and solving. These estimates of technical efficiency are also shown in Table 4.25. It may be important to note that $\partial\pi_a^i/\partial A_i > 0$, that is, actual profit always increases with the level of technical efficiency for given normalized input prices and k^i. The ranking of the technical efficiency between groups of retail stores is exactly the same as the ranking of economic efficiency. However, no statistical test of the differences in the relative technical efficiencies will be presented here.

Summary

In summary, the UOP profit model was used to compare the relative economic efficiency of four groups of retail firms, medium and large retail stores which utilize the carcass or fabricated beef handling system. Tests of relevant hypotheses indicated that relative economic efficiency varied across the four groups of firms. This variation of relative economic efficiency was significant with respect to medium sized stores which use the carcass beef handling system and two other groups of firms, large sized stores which use the carcass system and large sized stores that use the fabricated system. In each case the medium carcass stores were less efficient.

In addition, the relative price efficiency of the variable inputs, meat and labor, for each of the four groups of firms, were estimated from their respective derived input demand functions. Again tests of the relevant hypothesis indicated that the relative price efficiency of both, meat and labor, varied across the four groups of firms. When the source of this variation was examined, it was found that medium sized retail stores with the carcass handling system were different with respect to pricing efficiency of both meat and labor, than all of the other groups. There was no significant difference in the relative price efficiency of meat or labor between any of the remaining groups.

But, the question of which groups of firms are most pricing efficient, still remains to be answered. Two statistical testing procedures were used in an attempt to test the null hypothesis of profit maximization for each of the four groups of firms, with respect to meat and labor. However, both testing procedures proved to be inadequate, in that they both failed to meet the necessary assumptions underlying their respective test statistic. Hence, if the reader is willing to make certain assumptions, it appears that medium sized stores that use the carcass beef handling system are not maximizing profit with respect to the variable input meat, while all other groups of firms seem to be maximizing profits with respect to both meat and labor. But, one can recall that there was a significant difference in the relative pricing efficiency between medium carcass stores and all the other groups with respect to labor. Even though the test criterion for all of the other groups of stores is not statistically significant, it is obvious that the extent to which these samples depart from the null hypothesis is greater than the test criterion for medium carcass stores. Therefore, with respect to both variable inputs, taken together, the degree of relative pricing efficiency is inconclusive.

The last statistical test did not deal with efficiency, but simply tested the degree of returns to scale with respect to the UOP profit function. For the variables included in this study, this test indicated that there were constant returns to scale in all inputs for the Cobb-Douglas UOP profit function.

Economic Implications

The economic implications of this study hinge on the conceptual and empirical relevance of the preceding measures of relative technical, pricing and economic efficiency. Hence, it is imperative to briefly review the conceptual differences in the models in an attempt to later establish when each model is most germane to the specific economic issues being addressed.

Assuming that the frontier model, with constant returns to scale, and the profit model, are both neutral with respect to differences in production functions due to technological change, what differences exist between the models which might effect the economic implications of the study? Briefly stated, there are two basic differences: (1) the frontier model utilizes a subset of data to estimate the production function, while the profit model employs least squares as an estimation technique, which minimizes the sum of the squares of the errors taken over the entire sample; and (2) the profit model assumes that all firms attempt to maximize profits, while the frontier model does not consider relative product price differences.

One economic question that might be addressed is, when and how might technological changes come about in the handling of retail beef? This question was not pursued directly in this thesis since the research focused on efficiency and not diffusion. However, a few observations may be made. It is a generally accepted argument that there is a cost to economic knowledge and that resolving uncertainty takes time. Thus factors that affect the rate of technological diffusion include not only the profitability of the innovation, but the degree of uncertainty about the profitability and the means by which the uncertainty can be resolved. The speed of innovation is affected by such factors as education, and in this case technical knowledge of the meat industry. That is, the most qualified people are best suited to appraise the profitability of the technique a priori. Firms without the education or technical resources must await the results from these innovative firms before being convinced that the new technique is profitable.

More specifically, the frontier model estimated in this study indicates that there is a potential to lower costs via new technology, and given the same output price, a firm should be able to increase profits. But the profit model, which estimates average profits given all the observations, shows that normalized profits for large stores with the carcass system are not significantly different from the profits of large stores which use the fabricated system. This insignificance indicates that there will be a reluctance on the part of some large size carcass stores to convert to the fabricated system, due to the uncertainty of increasing profits. It appears then that both the carcass and fabricated handling systems will continue to exist within the beef retailing industry.

We may now turn to economic implications which are more specifically addressed in this study. Both economic models investigate the relative economic efficiency of alternative size retail meat operations which utilize the carcass or fabricated handling systems of beef in the Pacific Northwest. The frontier model indicates that medium and large stores using the fabricated system, as a group, have approximately five percent lower average costs than stores using the carcass handling system. Hence, the relative economic efficiency of firms in this sample using the fabricated system is higher than firms using the carcass system. This difference is mainly attributed to the apparent technological advantages of the fabricated system. That is, the relative technical efficiency of fabricated stores is greater than the average technical efficiency of stores with the carcass system, while there appears to be no significant difference in the relative pricing efficiency between the groups. However, it is imperative that the reader recall that the frontier model assumes that size does not affect the relative efficiency measures. That is, the separate effects of size and change in technology are unknown. The assumptions of the variation of the frontier model taking size into account were not met in this sample and as a result the Farrell and Fieldhouse model could not be used.

The results of the profit model are cast in a slightly different light. Besides the theoretical differences previously described, a differentiation in efficiency due to size could be included without violating the basic assumptions necessary for the validity of the model. In testing for equal relative economic efficiency, medium size stores which use the carcass beef system are significantly less efficient than large stores, regardless of their meat handling system. The cause of this inefficiency is not clear, in that the significance of differences in pricing and technical efficiency between each of the groups of stores could not be tested from the statistical results.

If the pricing efficiencies for each size group are ranked, without having a test of signficance, the medium carcass group was least efficient with respect to meat, followed by large carcass and medium fabricated with large fabricated being most efficient. On the other hand, medium carcass stores are most efficient with respect to labor, followed by large carcass and medium fabricated with large fabricated being least efficient. That is, the carcass stores were less pricing efficient with respect to meat than were the fabricated stores but more pricing efficient with respect to labor. It would appear then that institutional labor requirements, coupled with the lumpiness of labor as an input, cause the conversion from carcass to fabricated handling systems to be less attractive than would be the case in the absence of these constraints. The gain in pricing efficiency from a fabricated system accrues to meat as an input. This gain is dampened by the inability to alter the labor input level in retail meat departments.

There is also a difference in the technical efficiencies of medium size carcass and fabricated stores. It would appear from the parameters of the profit model that the technical efficiency of medium carcass stores could be increased by approximately seven percent if they have the desire and opportunity to change to a fabricated system.

The unit of study in this thesis is the individual retail store. It is obvious that additional benefits may be realized by vertically integrated organizations, independents and chain stores, which convert to a fabricated system. These implications may be important to the industry, but are beyond the scope of this study.

V. SUMMARY AND CONCLUSIONS

Summary

The packer-retail segment of the beef distribution system in the United States is undergoing one of its first major technological changes since the 1920's. Beef, which traditionally has moved through the system in carcass form, is now being centrally fabricated at the packer or wholesale level, eliminating these functions at the retail store. The fabricated system has several advantages, which, *a priori* indicate that retail firms which utilize this new system should be relatively more efficient than retail stores which use the carcass beef handling system. However, there is very little public information concerning the relative efficiencies between stores using the two systems. The purpose of this study is to conceptually and empirically define relative technical, pricing and economic efficiency between sample retail stores which use the two beef handling systems in the Pacific Northwest.

Two conceptual models, the frontier and the profit models, are used to define each measure of relative efficiency. Each model uses microeconomic production theory as a skeleton for analysis. The frontier approach estimates the frontier production function, that surface which represents the maximum possible output that can be produced by any given combination of input factors, given the cost constraints of the firm. Once the surface is estimated, the relative efficiencies of each firm can be computed.

However, the relevant issue in this study is the relative efficiency of two groups of firms with different technologies. In this specific instance, an unbiased measure of efficiency will only be obtained when the production functions, associated with each technology, are neutral. This is a necessary assumption in each of the models.

An alternative model is the profit function which assumes that all firms attempt to maximize profits. Given this assumption, Lau (1972) shows that every convex profit function has a dual which is a concave production function. Therefore, without loss of generality, relative efficiency can be estimated using only profit functions without an explicit specification of the corresponding production function. Relative efficiency between groups of retail stores is defined in this model, as the difference between the estimated profits of each group.

In addition, the importance of scale, relative to the efficiency of each group of firms, is also considered in this study. However, the frontier model, with scale included, was found to be invalid because of specification error. Therefore, the frontier model estimates shown herein, originate from a model which assumes constant returns to scale. The profit model handles scale by including two groups of firms in the analysis, medium and large size stores.

The empirical results of the frontier model indicate that the average cost of retail stores using the fabricated beef handling system are five percent lower than the average cost of reatil stores using carcass beef. This implies that the relative economic efficiency of stores on a fabricated system is greater than the economic efficiency of carcass stores. This difference in economic efficiency is attributed to a relatively large technical efficiency for the stores utilizing a fabricated beef system. In addition, there is no significant difference in the average pricing efficiencies between groups of stores using the two systems.

The profit model, which includes a scale effect, compares the relative economic efficiencies of four groups of retail firms, medium and large stores which utilize the carcass or fabricated beef handling system. Tests of relevant hypotheses indicate that relative economic efficiency varies across groups or firms in the study. This variation is significant with respect to medium size stores which use the carcass beef system and two other groups of firms, large size stores employing the carcass system and large size stores utilizing the fabricated system. In each case the medium carcass stores are less efficient.

Tests of the relative price efficiency of the variable inputs, meat and labor, for each of the four groups of firms, indicate that medium size stores using the carcass system are different with respect to pricing efficiency of both variable inputs, than all of the other groups. But, the question of direction and magnitude of the difference in pricing efficiency must still be answered.

Two statistical testing procedures are used in an attempt to test the null hypothesis of profit maximization, for each group of firms, with respect to meat and labor. However, both testing procedures prove to be inadequate, in that they both fail to meet the necessary assumptions underlying their respective test statistic. But, under certain assumptions it appears that medium size stores using carcass beef are less pricing efficient with respect to meat than all the other groups. On the other hand, medium carcass stores are more pricing efficient than the other groups with respect to labor. Hence, when both variable inputs are taken together, the degree of relative pricing efficiency is inconclusive.

Using information from both models, there is strong evidence that the scale of the retail store may be an important factor in determining efficiency. That is, the key to efficiency may simply lie in the ability to become large. However, there is some indication that medium size stores presently preparing carcass beef at the retail level, may lower costs and increase profits if they have the desire and opportunity to change to a fabricated system.

Limitations and Recommendations for Future Research

Limitations and recommendations for improvement of this empirical work are divided into two categories--(1) those which are possible to improve upon given the same basic data sources and (2) those which can be improved only by using a different approach or data sources.

The estimation of frontier isoquants is a natural first step in explaining technological change. The direction of the change and the neutrality of the change are two important facts to know. However, the Farrell model, which is used in this study, is only applicable in addressing these facts in a two input case. Since there is no a priori reason for supposing technical change to be neutral, as assumed in this study, another technique for judging the extent and direction of any nonneutrality may be most welcome. A study which intends to make this type of evaluation could follow the format of Aigner and Chu (1968), Timmer (1970) or Brown (1966).

In addition to showing technical efficiency in a quantitative manner, this study would have greatly benefited from an explanation of efficiency based on additional factors which were not included in this study. That is, the age, educational level and years of experience of the management, as well as store location, competition and information about the retail clientele, may all be factors which influence efficiency. These and other similar factors could also be used to explain and possibly predict the diffusion of technological change.

Similarly, the measure of efficiency in this study does not consider non-quantitative improvements which might accrue from a change in technology. That is, the advantages of a fabricated system such as longer shelf life because of better inventory control, better sanitation standards, and less time required to train qualified meat cutters, have not specifically been measured.

However, the most crucial limitation of this study, and the area which seems most fruitful for further research, is the fact that this study simply deals with the retail sector of the meat industry. Traditionally, the packer has not been retail oriented. Therefore, if the packer is providing the fabricated beef, there may be severe problems in coordinating beef specifications which are acceptable to both the packer and the retail sector. In addition, the number and size of packers or wholesalers providing fabricated beef in a specific marketing area will significantly influence the industry standards and information system of all firms within that market. All of these factors could influence technical and pricing efficiency, which in turn would influence the economic efficiency of retail stores.

BIBLIOGRAPHY

Aigner, Dennis J. and S. F. Chu. 1968. On estimating the industry production function. American Economic Review 58:826-839.

Beef Industry Council. 1972. A steer's not all steak.

Boles, James N. 1967. Efficiency squared-efficient computation of efficiency indexes. In: Proceedings of the Western Farm Economics Association, Los Angeles, 1966, ed. by M.V. Waananen. Pullman, Washington State University. p. 137-142.

__________ 1971. The 1130 Farrell efficiency system-multiple products, multiple factors. Berkeley, University of California. 91 p. (Giannini Foundation of Agricultural Economics)

__________ 1973. The measurement of productive efficiency: the Farrell approach. Unpublished monograph. University of California, Berkeley. 27 numb. leaves.

Bressler, Raymond G. 1967. The measurement of productive efficiency. In: Proceedings of the Western Farm Economics Association, Los Angeles, 1966, ed. by M.V. Waananen. Pullman, Washington State University. p. 129-136.

Bressler, Raymond G. and Richard A. King. 1970. Markets, prices, and interregional trade. New York, John Wiley and Sons, Inc. 426 p.

Brown, Murray. 1966. The theory and measurement of technological change. Cambridge, Cambridge University Press. 214 p.

Carlson, Sune. 1956. A study on the pure theory of production. New York, Kelley and Millman, Inc. 128 p.

Draper, N.R. and H. Smith. 1966. Applied regression analysis. New York, John Wiley and Sons, Inc. 407 p.

Duewer, Lawrence A. and Wilber R. Maki. 1966. A study of the meat products industry through systems analysis and simulation of decision units. Agricultural Economics Research 18:79-83.

Duewer, Lawrence A. 1970. Price spreads for beef and pork, revised series 1949-1969. Washington, D.C. 14 p. (Economic Research Service, U.S. Department of Agriculture. Miscellaneous Publication No. 1174)

Erickson, Donald B. and Richard W. Lichty. 1972. A cost analysis of alternative fresh and frozen meat distribution systems. In: Frozen meat distribution systems research study, final report. Manhattan. p. 51-58. (Kansas Agricultural Experiment Station. Final Report)

Farrell, Michael J. 1957. The measurement of productive efficiency. The Journal of the Royal Statistical Society 120:253-290.

Farrell, Michael J. and M. Fieldhouse. 1962. Estimating efficient production functions under increasing returns to scale. The Journal of the Royal Statistical Society 125:252-267.

French, D.C., L.L. Samuret and R.G. Bressler. 1956. Economic efficiency in plant operations with special reference to the marketing of California pears. Hilgardia 24:543-721.

Friedman, Milton. 1968. The methodology of positive economics. In: Readings in microeconomics, ed. by William Breit and Harold M. Hochman, New York, Holt, Rinehart and Winston, Inc. p. 23-47.

Garrod, Peter V. 1973. Disaggregation of measures of relative efficiency. Working paper. Department of Agricultural and Resource Economics. University of Hawaii. 26 numb. leaves.

Henderson, James M. and Richard E. Quant. 1958. Microeconomic theory. New York, McGraw-Hill. 291 p.

Hildreth, C. and F.G. Jarrett. 1955. A statistical study of livestock production and marketing. New York, John Wiley and Sons, Inc. 156 p.

Hock, Irving. 1958. Simultaneous equation bias in context of Cobb-Douglas production function. Econometrica 26:566-578.

Hoecker, R.W. 1962. Centralized processing of fresh meat for retail stores. Washington, D.C. 33 p. (Marketing Research Report, U.S. Department of Agriculture. Report No. 629)

Holloway, Milton Lee. 1972. A production function analysis of water resource productivity in Pacific Northwest agriculture. Ph.D. thesis. Corvallis, Oregon State University. 205 numb. leaves.

Huang, David S. 1970. Regression and econometric methods. New York, John Wiley and Sons, Inc. 274 p.

Ives, J. Russell. 1966. The livestock and meat economy of the United States. Ann Arbor, Michigan, Edwards Brothers, Inc. 227 p.

Kearney, A. T. and Co., Inc. 1969. Feasibility of a physical distribution system model for evaluating improvements in the cattle and fresh beef industry. Hyattsville, Md. 63 p. (Agricultural Research Service Bulletin No. 52-36, U.S. Department of Agriculture)

Kmenta, Jan. 1971. Elements of econometrics. New York, The Macmillan Co. 655 p.

Kohls, Richard L. 1967. Marketing of agricultural products. New York, The Macmillan Co. 462 p.

Koopmans, Tjalling. 1958. Three essays on the state of economic science. New York, McGraw-Hill. 231 p.

Lau, Lawrence J. 1972. Applications of profit functions. In: An econometric approach to production theory, ed. by D.L. McFadden. Amsterdam. Forthcoming.

Lau, Lawrence J. and Pan A. Yotopoulos. 1971. A test for relative efficiency and application to Indian agriculture. American Economic Review 61:94-109.

Leibenstein, Harvey. 1966. Allocative efficiency vs. 'x-efficiency.' American Economic Review 56:392-415.

Maki, W.R. and R.J. Crom. 1965. Evaluating alternative meat organizations in a simulated livestock-meat economy. Ames. 44 p. (Iowa Agriculture and Home Economics Experiment Station. Research Bulletin No. 541)

McFadden, D.L. 1972. Cost, revenue, and profit functions. In: An econometric approach to production theory, ed. by D.L. McFadden. Amsterdam. Forthcoming.

Meat cutters #143 retail agreement. 1973. Portland, Oregon. 13 numb. leaves.

Nelson, Richard R. and Edmund S. Phelps. 1966. Investment in humans, technological diffusion, and economic growth. American Economic Review 56:69-75.

Nerlove, Marc. 1965. Estimation and identification of Cobb-Douglas production functions. Chicago, Rand McNally and Co. 193 p.

Padberg, Daniel I. 1968. Economics of food retailing. Ithaca, Cornell University Press. 292 p.

Rao, Potluri and Roger LeRoy Miller. 1971. Applied econometrics. Belmont, California, Wadsworth Publishing Company, Inc. 235 p.

Seitz, Wesley D. 1967. Efficiency measures for steam electric generating plants. In: Proceedings of the Western Farm Economics Association, Los Angeles, 1966, ed. by M.V. Waananen. Pullman, Washington State University. p. 143-151.

__________ 1968. The measurement of productive efficiency. Ph.D. thesis. Berkeley, University of California. 195 numb. leaves.

__________ 1970. The measurement of efficiency relative to a frontier production function. American Journal of Agricultural Economics 52:505-511.

__________ 1971. Productive efficiency in the steam-generating industry. Journal of Political Economy 79:878-886.

Shaw, Seth T. and S. Kent Christensen. 1973. NAFC report on meat: the move to centralization. Report to the National Association of Food Chains 40th annual meeting, Washington, D.C. 16 p.

Simon, Herbert A. 1959. Theoreies of decision-making in economics and behavioral science. American Economic Review 49:253-283.

Sitorus, Bistok. 1967. Productive efficiency and redundant factors of production in traditional agriculture of underdeveloped countries: a note on measurement. In: Proceedings of the Western Farm Economics Association, Los Angeles, 1966, ed. by M.V. Waananen. Pullman, Washington State University. p. 153-518.

Smith, G.C. and Z.L. Carpenter. 1972. Further studies of concepts for possible improvements in marketing, distributing and merchandising of lamb. College Station 317 p. (Texas Agriculture Experiment Station. Special report)

Snedecor, George W. and William G. Cochran. 1967. Statistical methods. Ames, Iowa State University Press. 593 p.

Supermarketing. November, 1973. 28:1-30.

The value line investment survey. 1974.

Theil, Henri. 1954. Linear aggregation of economic relations. Amsterdam, North Holland Publishing Co. 205 p.

Timmer, C.P. 1970. On measuring technical efficiency. Food Research Institute studies in agricultural economics, trade and development 9:99-169.

Timmer, C.P. 1971. Using a probabilistic frontier production function to measure technical efficiency. Journal of Political Economy 79:776-794.

Tuma, Harold et al. 1973. Frozen meat: it's distribution costs, acceptance, and cooking and eating qualities. Manhattan. 78 p. (Kansas Agricultural Experiment Station. Research publication 166)

U.S. Department of Agriculture. 1968. Consumer and Marketing Service. USDA yield grades for beef. Washington, D.C. 19 p. (Marketing Bulletin No. 45)

Uzawa, H. 1964. Duality principles in the theory of cost and production. International Economic Review 5:216-220.

Vignieri, Charles. 1971. Why we got into our market ready beef program. Meat Processing. p. 3-5.

Viner, Jacob. 1952. Cost curves and supply curves. In: A.E.A. readings in price theory, ed. by K.G. Boulding and G.J. Stigler, Chicago, Richard D. Irwin, Inc. p. 198-232.

Walters, A.A. 1963. Production and cost functions: an economic survey. Econometrica 31:1-66.

Weatherly, E., Wendell Earle, and Earl Brown. 1967. Alternative methods of meat distribution. Ithaca. 47 p. (Cornell University Department of Agricultural Economics Report No. 232)

Wise, John and Pan A. Yotopoulos. 1969. The empirical content of economic rationality: a test for a less developed economy. Journal of Political Economy 77:976-1004.

Yamane, Taro. 1964. Statistics, an introductory analysis. New York, Harper and Row. 735 p.

Yotopoulos, Pan A. 1967. From stock to flow capital inputs for agricultural production functions; a micro-analytic approach. Journal of Farm Economics 49:476-491.

Yotopoulos, Pan A., Lawrence J. Lau, and Kutlu Somel. 1970. Labor intensity and relative efficiency in Indian agriculture. Food Research Institute studies in agricultural economics, trade and development 9:43-56.

Yotopoulos, Pan A. and Lawrence J. Lau. 1973. A test for relative economic efficiency: some further results. American Economic Review 63:214-223.

Youde, J.G. and C.W. O'Connor. 1973. Fresh and frozen beef retailing by independent grocery stores in Oregon: characteristics and comparisons. Corvallis. 37 p. (Oregon Agricultural Experiment Station. Circular of Information 640).

APPENDICES

APPENDIX A

Summary Data for 42 Retail Stores,
Pacific Northwest, February, 1973

Table A-1. Summary data for 21 retail stores with carcass beef handling systems, February, 1973.

Firm ID.	Average Weekly Meat Sales (Hundred Dollars)	Wholesale Pounds Meat*	Average Weighted Wholesale Meat* Price	Man-Hours	Average Wage Rate	Service Flow of Capital	Total Cost	Retail Pounds Meat*	Average Weighted Retail Meat* Price	Total Revenue	Profit
101	52	17322	.717	529	4.818	301.45	15269.05	15254	1.006	15346.07	77.02
102	22	5712	.707	290	5.125	228.62	5756.02	4854	1.050	5094.71	-661.31
103	62	16335	.695	476	4.910	316.09	14007.80	14427	1.007	14525.92	518.12
104	54	15531	.707	448	5.086	316.93	13579.16	13340	1.038	13848.11	268.95
105	87	27033	.670	621	4.805	355.00	21443.79	24026	.982	23602.67	2158.88
106	64	20425	.696	511	4.987	522.30	17288.20	17930	1.045	18736.16	1447.96
107	20	5750	.767	192	5.875	250.63	5790.71	4985	1.034	5156.39	-634.32
108	41	11633	.701	304	5.039	299.10	9990.64	10175	1.012	10296.27	305.63
109	15	4757	.644	164	5.125	214.86	4119.44	4202	.944	3966.40	-153.04
110	22	8431	.710	192	5.820	234.18	7335.12	7593	1.050	7973.34	638.22
111	100	36049	.670	704	4.722	411.65	27906.45	32681	1.002	32740.24	4833.79
112	120	41637	.687	904	4.810	442.43	33403.75	37247	1.003	37356.01	3952.26
113	86	21249	.688	612	4.927	324.94	17951.61	18505	1.016	18804.14	852.53
114	52	15600	.669	360	4.902	317.00	12523.70	13691	.970	13285.01	761.31
115	41	12197	.734	400	4.810	270.71	11145.33	10442	1.038	10842.36	-302.97
116	140	42656	.660	962	4.801	381.48	33169.70	37916	.984	37302.93	4133.23
117	49	15090	.698	512	4.863	237.54	13265.56	13415	.981	13156.03	-109.53
121	150	47634	.714	905	4.820	401.93	38787.48	40351	1.067	43045.11	4257.63
122	160	49473	.700	931	4.800	432.23	39509.03	42245	1.048	44290.65	4781.62
123	160	47060	.722	1000	4.780	469.94	39247.41	39852	1.063	42353.94	3106.56
124	200	62859	.698	1161	4.797	483.37	49930.70	54057	1.041	56267.05	6336.35

*Meat is defined as beef, pork, poultry and lamb.

Table A-2. Summary data for 21 retail stores with fabricated beef handling systems, February, 1973.

Firm ID.	Average Weekly Meat Sales (Hundred Dollars)	Wholesale Pounds Meat*	Average Weighted Wholesale Meat* Price	Man-Hours	Average Wage Rate	Service Flow of Capital	Total Cost	Retail Pounds Meat*	Average Weighted Retail Meat* Price	Total Revenue	Profit
404	59	12619	.804	310	4.955	253.51	11934.31	11937	1.153	13762.88	1828.58
418	77	14960	.763	380	4.851	273.12	13533.35	14012	1.133	15879.24	2345.89
419	83	18620	.788	467	4.861	339.41	17280.57	17366	1.155	20059.95	2779.39
417	83	17213	.787	404	4.853	348.07	15849.49	16188	1.143	18500.94	2651.45
401	86	15457	.788	477	4.860	266.59	14767.67	14615	1.156	16899.42	2131.75
403	110	23526	.797	500	4.771	414.74	21560.81	22175	1.155	25608.10	4047.29
416	120	21340	.787	372	4.849	368.52	18960.00	20100	1.148	23072.46	4112.46
413	120	26298	.799	685	4.807	452.53	24754.69	24756	1.168	28914.44	4159.75
408	120	26094	.793	585	4.867	595.08	24143.08	24444	1.163	28436.73	4293.65
405	140	30634	.812	608	4.795	457.65	28239.03	28628	1.155	33067.52	4828.50
415	150	29905	.745	731	4.773	420.69	26175.77	27456	1.156	31738.71	5562.94
414	160	33112	.824	598	4.741	414.61	30541.42	30933	1.154	35693.11	5151.69
409	220	48928	.791	1073	4.813	458.25	44330.61	45239	1.157	52362.57	8031.96
421	30	4802	.803	192	5.552	224.43	5145.36	4514	1.149	5186.68	41.31
422	30	7258	.792	205	5.432	247.50	7112.23	6774	1.159	7847.85	735.62
423	40	7710	.783	225	5.330	232.76	7471.72	7228	1.150	8309.81	838.09
424	49	9824	.804	247	4.963	277.15	9399.35	9240	1.151	10637.46	1238.11
425	49	10005	.799	232	5.284	316.29	9533.43	9353	1.154	10792.14	1258.70
426	51	10164	.780	251	5.201	275.08	9503.77	9508	1.145	10890.03	1386.26
427	54	10849	.784	276	5.064	264.15	10165.71	10167	1.145	11639.00	1473.29
428	30	5021	.809	210	5.432	228.45	5429.58	4723	1.150	5430.40	.82

*Meat is defined as beef, pork, poultry and lamb.

APPENDIX B

Survey Data for 32 Retail Stores Used
in Estimating Relative Efficiency

Table B-1. Data used in estimating technical efficiency, the Farrell and Fieldhouse model.

Store ID.	Pounds of Retail Meat	Pounds of Wholesale Meat /Pounds of Retail Meat	Man-Hours /Pound of Retail Meat	Service Flow of Capital /Pound of Retail Meat	Average Weekly Meat Sales (Scale) (Thousands of Dollars)
103	1.0	1.13225	.03299	.02191	5
104	1.0	1.16424	.03358	.02376	5
105	1.0	1.12516	.02585	.01478	8
106	1.0	1.13915	.02850	.02913	5
108	1.0	1.14329	.02988	.02940	5
111	1.0	1.10306	.02154	.01260	11
112	1.0	1.11786	.02427	.01188	11
113	1.0	1.14828	.03307	.01756	8
114	1.0	1.13943	.02629	.02315	5
116	1.0	1.12501	.02537	.01006	15
121	1.0	1.18049	.02243	.00996	15
122	1.0	1.17110	.02204	.01023	15
123	1.0	1.18087	.02509	.01179	15
124	1.0	1.16283	.02148	.00894	15
404	1.0	1.05713	.02597	.02124	8
418	1.0	1.06766	.02712	.01949	8
419	1.0	1.07221	.02689	.01954	8
417	1.0	1.06332	.02496	.02150	8
401	1.0	1.05761	.03264	.01824	8
403	1.0	1.06092	.02255	.01870	11
416	1.0	1.06169	.01851	.01833	11
413	1.0	1.06229	.02767	.01828	11
408	1.0	1.06750	.02393	.02434	11
405	1.0	1.07007	.02124	.01599	15
415	1.0	1.08920	.02662	.01532	15
414	1.0	1.07044	.01933	.01340	15
409	1.0	1.08154	.02372	.01013	15
423	1.0	1.06669	.03113	.03220	5
424	1.0	1.06320	.02673	.02999	5
425	1.0	1.06971	.02480	.03382	5
426	1.0	1.06899	.02640	.02893	5
427	1.0	1.06708	.02715	.02598	5

Table B-2. Data used in estimating relative efficiency, the UOP profit model.

Store ID.	Profit/Ave. Retail Meat Price	Wholesale Meat Price/Ave. Retail Meat Price	Wage Rate/Ave. Retail Meat Price	Service Flow of Capital
103	514.59	.69037	4.87656	316.09
104	259.08	.68126	4.89939	316.93
105	2197.60	.68174	4.89118	355.00
106	1385.66	.66613	4.77242	522.30
108	302.04	.69316	4.97965	299.10
111	4825.04	.66830	4.76337	411.65
112	3940.73	.68520	4.79596	442.43
113	838.97	.67669	4.84862	324.94
114	784.57	.68981	5.05181	317.00
116	4201.16	.67124	4.87990	381.48
121	3991.16	.66956	4.51833	401.93
122	4560.77	.66722	4.57830	432.23
123	2923.04	.67975	4.49763	469.94
124	6087.47	.67062	4.69858	483.37
404	1585.98	.69727	4.29763	253.51
418	2070.03	.67342	4.28057	273.12
419	2406.13	.68211	4.20819	339.41
417	2319.98	.68831	4.24629	348.07
401	1843.59	.68163	4.20304	266.59
403	3504.70	.69053	4.13139	414.74
416	3582.64	.68533	4.22430	368.52
413	3561.50	.68400	4.11566	452.53
408	3690.79	.68193	4.18364	595.08
405	4180.24	.70274	4.15124	457.65
415	4812.29	.64409	4.12895	420.69
414	4464.65	.71430	4.10873	414.61
409	6939.27	.68350	4.15822	458.25
423	728.98	.68138	4.63612	232.76
424	1075.46	.69819	4.31100	277.15
425	1090.85	.69222	4.57938	316.29
426	1210.33	.68061	4.54095	275.08
427	1286.96	.68471	4.42355	264.15

APPENDIX C

Ten Efficiency Indices from the Farrell or Farrell and Fieldhouse Model for 32 Retail Stores

Store ID.	TEC	PEC	EEC	TES	PES	EES	TSE	PSE	ESE	EE
<u>$5,000 Scale*</u>										
103	.934	.935	.873	1.000	.926	926	.989	.883	.873	.808
104	.908	.934	.848	.960	.938	.900	.949	.894	.848	.763
106	.928	.949	.881	.938	.998	.936	.927	.950	.881	.825
108	.925	.943	.872	.932	.922	.925	.922	.946	.872	.807
114	.929	.964	.896	1.000	.953	.953	.989	.906	.896	.854
423	.991	.926	.918	.997	.974	.971	.986	.931	.918	.891
424	.994	.953	.947	1.000	.999	.999	.989	.958	.947	.946
425	.989	.957	.946	1.000	1.000	1.000	.989	.957	.946	.946
426	.989	.957	.946	.999	.998	.997	.988	.957	.946	.943
427	.991	.953	.944	1.000	.998	.998	.989	.954	.944	.942
<u>$8,000 Scale*</u>										
105	.950	.965	.917	1.000	.957	.957	1.000	.917	.917	.878
113	.926	.934	.865	.948	.953	.903	.948	.912	.865	.781
404	1.000	.964	.964	1.000	1.000	1.000	1.000	.964	.964	.964
418	.991	.960	.951	1.000	.988	.988	1.000	.951	.951	.940
419	.987	.961	.949	.997	.988	.985	.997	.952	.949	.935
417	.995	.969	.964	.997	1.000	.997	.997	.967	.964	.961
401	1.000	.935	.935	1.000	.971	.971	1.000	.935	.935	.908

Store ID.	TEC	PEC	EEC	TES	PES	EES	TSE	PSE	ESE	EE
$11,000 Scale*										
111	.974	.983	.957	1.000	.957	.957	1.000	.957	.957	.916
112	.964	.968	.933	1.000	.933	.933	1.000	.933	.933	.870
403	.999	.981	.980	1.000	.980	.980	1.000	.980	.980	.960
416	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
413	.997	.963	.960	.999	.961	.960	.999	.961	.960	.922
408	.992	.971	.963	.994	.969	.963	.994	.969	.963	.927
$15,000 Scale*										
116	.979	.943	.923	.979	.949	.929	.979	.943	.923	.857
121	.965	.934	.901	.965	.939	.906	.965	.934	.901	.816
122	.969	.938	.909	.969	.943	.914	.969	.938	.909	.831
123	.914	.972	.888	.916	.975	.893	.916	.969	.888	.793
124	.983	.987	.971	1.000	.977	.977	1.000	.971	.971	.949
405	.996	.986	.982	1.000	.988	.988	1.000	.982	.982	.970
415	.979	.961	.941	.983	.963	.947	.983	.957	.941	.891
414	1.000	.994	.994	1.000	1.000	1.000	1.000	.994	.994	.994
409	1.000	.967	.967	1.000	.973	.973	1.000	.967	.967	.941

*Average weekly sales are used as a proxy variable for scale.