COST ANALYSIS OF THE STEER AND HEIFER PROCESSING INDUSTRY AND IMPLICATIONS ON LONG-RUN INDUSTRY STRUCTURE

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INDUSTRY STRUCTURE

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CHAPTER I

INTRODUCTION

Background

The structure of the steer and heifer slaughter industry is undergoing significant changes. Researchers, industry participants, and government officials are concerned with the effectsstructural changes will have on the conduct of firms, and performance of the industry (Ball and Chambers, 1982). High firm concentration and market dominance is not new to the meatpacking industry. The four largest firms in the meatpacking industry accounted for 50 percent of total production during the 1920's (Williams, 1979). The steer and heifer slaughter industry is once again becoming dominated by a few firms. The largest firm in 1978: (1) slaughtered more than twice as many steers and heifers as its nearest competitor; (2) controlled 35 to 40 percent of the boxed beef market; and (3) may have been the largest buyer of beef carcasses from other packers in 1978 (Ball and Chambers, 1982).

The meatpacking industry has moved over the past 100 years from local Eastern packers to the present multiplant, integrated slaughter and fabrication firms located in the Corn Belt and Southern Plains. Slaughter cattle sales were centralized at public terminal markets by the late 1800's (Packers and Stockyards Administration, 1979). Meatpacking firms followed the supply of slaughter cattle, locating near terminal public markets. Procurement, processing, and distribution costs declined as plant size increased, encouraging meatpacking firms to become larger (Packers and Stockyards Administration, 1979).

Between 1910 and 1918, the Big Five (Armour, Cudahy, Morris, Swift and Wilson) increased their percent of total slaughter from 38.3 to 55.1, a 44 percent increase (Packers and Stockyards Administration, 1979). A Federal Trade Commission investigation in 1917 concluded that the Big Five dominated the slaughter industry and distribution facilities (Packers and Stockyards Administration, 1979). The Consent Decrees of 1920, which resulted from the investigation by the Federal Trade Commission, directed the Big Five to divest of distribution and communication interests. A year later the Packers and Stockyards Act of 1921 was passed and the Packers and Stockyards Administration was formed within the United States Department of Agriculture. Its purpose was to regulate the livestock and meatpacking industry (Packers and Stockyards Administration, 1979).

The meatpacking industry decentralized and slaughter concentration declined from 1920 to 1950. Some of the factors contributing to decentralization were improved highways, improved market news services, and shifts in livestock production, coinciding with shifts in corn and other feed grain production (Packers and Stockyards Administration, 1979).

Technology changed the slaughter industry structure in the 1950's and early 1960's. Improved transportation, refrigeration,and communication were the general technological improvements. Specific improvements in the slaughter process were on-the-rail slaughtering, mechanical knives, and hide pullers (Packers and Stockers Administration, 1979).

Introduction and development of boxed beef changed the distribution methods and relative importance of the leading firms in the 1960's and

1970's (Packers and Stockyards Administration, 1979). Slaughter plants no longer shipped carcasses but fabricated the carcass into primal cuts (i.e., chuck, rib, loin, and round), vacuum sealed the cuts in plastic wrap, and boxed them for transporting. The product resulting from this technological change is commonly referred to as boxed beef.

The technology to produce boxed beef was introduced by new entrants into the steer and heifer slaughter industry (Williams, 1979). The new firms gained market share rapidly and began rivaling the Big Five for top position in the slaughter industry (Williams, 1979). New entrants decreased their labor costs by operating under renegotiated union contracts or operating nonunion plants with lower wage rates (Anderson, 1984). New entrants into the beef processing industry (i.e., slaughter and fabrication) have built single species, integrated slaughter and fabrication plants in the Corn Belt and Southern Plains states (Packers and Stockyards Administration, 1979). Single species, integrated plants located near the supply of slaughter cattle have a cost advantage in procurement and processing compared with the traditional multi-species plants of the 1950's (Williams, 1979).

Six of the largest meatpackers (Swift & Co., Armour & Co., Wilson Foods, Morrell, Cudahy, and Hygrade) were bought by conglomerates (Esmark, Greyhound, LTV, United Brands, General Host, and Hanson Trust, respectively) in the late 1960's and early 1970's (Anderson, 1981). The conglomerates divested their interests in the meatpacking firms by the early 1980's. Meatpacking firms once owned by conglomerates have changed ownership, closed, or slaughter fewer cattle than before they were bought by conglomerates (Anderson, 1985). Recently, the two largest steer and heifer processors were bought by conglomerates (Anderson, 1985).

Structural changes have centered around redistributing the slaughter volume away from many small plants to a few, large plants and multiplant firms in the past 10 to 15 years. Firms slaughtering less than 100,000 head annually decreased in number as well as in their percent of total slaughter by all firms reporting to the Packers and Stockyards Administration (Table 1). Firms slaughtering 500,000 head or more annually also decreased in number, but increased their percent of slaughter by all reporting firms. Firms in the size group that slaughtered 500,000 head or more annually were larger in 1982 than 1977. Firms slaughtering less than 50,000 head annually had the largest decrease in number of firms and in percent of slaughter by all reporting firms. Firms slaughtering between 10,000 and 99,999 head annually either closed or moved to a smaller or larger size group. One hundred forty-seven firms left the steer and heifer industry between 1977 and 1982. Thirty-five percent of all firms ceasing steer and heifer slaughter between 1977 and 1982 were from the size groups slaughtering less than 50,000 head annually (Packers and Stockyards Administration, 1984). At the same time, average slaughter per firm increased 15 percent (Packers and Stockyards Administration, 1984). There were 16.3 percent more firms slaughtering 30.6 percent fewer cattle in the smallest size group (i.e., less than 10,000 head slaughtered annually) in 1982 compared with 1977 (Table 1). In the size group that slaughtered 500,000 head or more annually the same number of firms slaughtered 25.6 percent more cattle in 1982 than in 1977.

Improvements such as refrigeration, on-the-rail slaughtering, mechanical knives, and hide pullers of the 1950's and 1960's along with fabrication of carcasses in the 1960's and 1970's have increased capital requirements in the steer and heifer slaughter industry (Williams, 1979).

Table 1. United States Steer and Heifer Slaughter by Packers Reporting in 1977 and/or 1982 By Size Groups

	Size Groups[a]						
	< 10,000	10,000-49,999	50,000-99,999	100,000-149,999	150,000-499,999	≥ 500,000	Total
Number of firms reporting steer and heifer slaughter in 1977	392	125	59	15	14	13	618
Percent of all firms reporting steer and heifer slaughter in 1977	63.4	20.2	9.6	2.4	2.3	2.1	100
Percent of slaughter by all reporting firms in 1977	3.6	9.6	14.2	6.1	14.4	52.0	99.9[b]
Number of firms reporting steer and heifer slaughter in 1982	347	62	28	13	11	10	417
Percent of all firms reporting steer and heifer slaughter in 1982	73.7	13.2	5.9	2.8	2.3	2.1	100
Percent of slaughter by all reporting firms in 1982	2.5	6.3	8.1	6.3	11.5	65.3	100

Table 1. (Continued)

	Size Groups[a]						
	< 10,000	10,000-49,999	50,000-99,999	100,000-149,999	150,000-499,999	≥ 500,000	Total
Percent change in number of firms reporting steer and heifer slaughter between 1977 and 1982	-11.5	-50.4	-52.5	-13.3	-21.4	-23.1	-23.8
Percent change in percent of all firms reporting steer and heifer slaughter in 1982	16.3	-34.7	-37.9	16.7	0	0	-39.6
Percent change in percent of slaughter by all reporting firms between 1977 and 1982	-30.6	-34.4	-43.0	3.3	-20.1	25.6	-99.2

[a]Number of head slaughtered annually.

[b]Does not sum to 100 due to rounding.

Source: Packers and Stockyards Administration, 1984.

Although fixed costs have increased over time, Schnittker Associates argue box beef technology has reduced total beef packing costs by $400 to $500 million per year. Plants operating in 1985 need to be larger relative to plant size in the past to spread the higher fixed costs over more units of output in order to keep average fixed cost low. Sawyer suggests there is a minimum efficient plant size, i.e., average processing costs of smaller plant sizes are significantly higher than average costs for larger plants, making operation of the smaller plants virtually impossible. Grieg (1976) cited economic engineering studies in meat slaughtering and processing that concluded the minimum efficient plant size was twice as large as the average size plant in 1963.

Problem Statement

Plants slaughtering 100,000 head or less annually have declined in percent of slaughter by all firms reporting steer and heifer slaughter since 1977 (Table 1). Plants reporting 500,000 head or more annually are increasing their share of total slaughter. In 1982, 2.1 percent of all firms reporting steer and heifer slaughter accounted for 65.3 percent of total slaughter.

In any industry, it is necessary for firms to cover costs and have a fair return to investment equity capital, in order to survive in the long run. One possible cause for the trend toward fewer and larger plants in the steer and heifer processing indstury is economies of size and scale.

Economies of size is a short-run concept, i.e., at least one factor of production is fixed (Gould and Ferguson, 1980). Plants with capacity fixed in the short-run can lower average fixed cost by increasing plant utilization. Management can increase plant utilization by working more hours per shift, more days per week, or more shifts per day. Short-run average total costs will decrease as utilization rate increases to a certain level. Thereafter, diminishing marginal returns causes increases in average variable cost to exceed decreases in average fixed cost, thus causing average total cost to increase (Mansfield, 1975).

The long-run parallel concept to economies of size is economies of scale. Economies of scale exist if, after adjusting all inputs optimally, the long-run average cost can be reduced by increasing plant size (Gould and Ferguson, 1980). Specialization of labor and technological factors are the two main production forces that enable entrepreneurers to reduce long-run average cost by expanding the scale of operation (Gould and Ferguson, 1980).

The base economies of scale study in meatpacking was by Logan and King in 1962. The objective of the Logan and King study was to determine the nature of the long run average cost curve for specialized beef slaughtering plants. Costs for slaughter plants were determined using the economic-engineering approach. The long-run average cost curve declined over the entire range of output considered in the study.

Cothern, Peard, and Weeks did a similar study in 1976. Again, the economic-engineering approach was used to determine slaughter and fabrication costs. They concluded that significant economies of scale existed in slaughter plants but only slight economies of scale existed in fabrication plants. The estimated long-run average cost curve declined throughout, with the most significant economies of scale being realized between the two largest plant sizes (110 and 300 head per hour).

Faminow and Sarhan (1983) updated slaughter and fabrication costs from the Cothern et al. study. Costs in 1976 were adjusted by an inflation factor to arrive at 1980 costs.

Past studies in the beef slaughter industry are outdated because plants are larger than the largest plant size considered by Logan and King (1962) and by Cothern et al. (1978). The economic-engineering approach assumes all plants are identical, i.e., same size, technology, utilization rate, management objectives, and costs. For example, plants are identical within an operating scenario (i.e., one 8-hour shift per day, 5 days per week, and 100 percent capacity) but differ between operating scenarios. Logan and King (1962) and Cothern et al. (1978) did not consider the affect of alternative hours worked per shift, days worked per week, number of shifts worked per day on long-run average cost. However, evidence indicates that plants in the steer and heifer slaughter industry range in size, technology, utilization rate, management objectives, and costs.

Purpose of Study

The purpose of this study is to determine whether or not recent structural changes in the steer and heifer slaughter industry can be explained by economies of size and scale. Specifically the objectives are:

1. To develop short-run and long-run average cost models for steer and heifer processing plants.

2. To determine the minimum efficient plant size or sizes for the steer and heifer processing plants.

3. To explain changes in the structure of the steer and heifer processing industry based on the nature of the long-run average cost curve.

4. To determine implications for the future structure of the steer and heifer processing industry, and its affects on conduct of firms, and performance of the industry.

Procedure

This is a brief overview of the procedures with a more detailed explanation presented in Chapter III. A questionnaire was developed and sent to firms which slaughtered and/or fabricated steers and heifers. It was felt industry participants would be most knowledgeable in estimating average costs under different operating conditions.

A binary regression model was constructed to explain the variation in average costs among plants of similar size and between plants of different sizes. Independent variables were specified in several alternative units to determine the best explanatory model. Models were constructed for slaughter and fabrication of steers and heifers and for each size group within slaughter and fabrication. Models for slaughter and fabrication were used to construct long-run average cost curves. From the long-run average cost curves for slaughter and fabrication, the minimum efficient plant size or sizes were determined. Then, the nature of the long-run average cost curve is used to draw inferences about the structure, conduct, and performance of the steer and heifer processing industry.

CHAPTER II

ECONOMIC THEORY

Conceptual Framework

This study is based on industrial organization theory and micro-economic theory of the firm. Industrial organization is concerned with how productive activities are brought into harmony with society's demands for goods and services through some organizing mechanism such as a free market and how variations and imperfections in the organizing mechanism affect the degree of success achieved by producers in satisfying society's wants (Scherer, 1980). Industrial organization begins with the fundamental assumption that a society wants producers of goods and services to perform well. The type of market organization linking producers with consumers is an important variable in industrial organization theory (Scherer, 1980. Performance of an economy is based on the performance of private enterprises (Bain, 1968). Private enterprise performance is measured by how well the market organization achieves the goals of society, i.e., providing employment, producing goods, and distributing income.

Market structure, conduct, and performance are used in evaluating how well market organizations satisfy society's goals. Market structure is the organizational characteristics, i.e., number of sellers and buyers, product differentiation and condition of entry of a particular market (Bain, 1968). Market conduct is the policies, practices, and devices firms employ in arriving at adjustments to the markets in which they participate. Market performance is the end result of firms operating in any market, i.e., prices paid and received, output, production and selling costs, and product design.

Figure 1 is a model of industrial organization analysis. Scherer (1980) shows a one-way directional relationship among basic conditions, market structure, conduct, and performance but there may well be a two-way directional relationship. There is a feedback loop between market conduct and structure, between market structure and basic conditions, and between market conduct and basic conditions.

One performance measure is production efficiency. If firms are producing less efficiently than possible, new firms maybe attracted to the industry, thereby altering market structure and possibly pricing behavior (market conduct).

Part of a firm's market conduct is legal tactics, i.e., enforcing patent rights. Patent rights may create barriers to entry. Firms in a protected market may have higher costs and prices than they would have in a market without barriers to entry.

As the concentration of buyers in an industry increases, the supply of raw materials is controlled by a few large buyers. If the concentration of sellers increases, demand becomes less price elastic. Firms acting as both buyers and sellers that are highly concentrated may well control the supply of raw materials and the demand for final products.

One component of market conduct is research and innovation. On the supply side, research often leads to improved technology and innovation may well increase the demand for products.

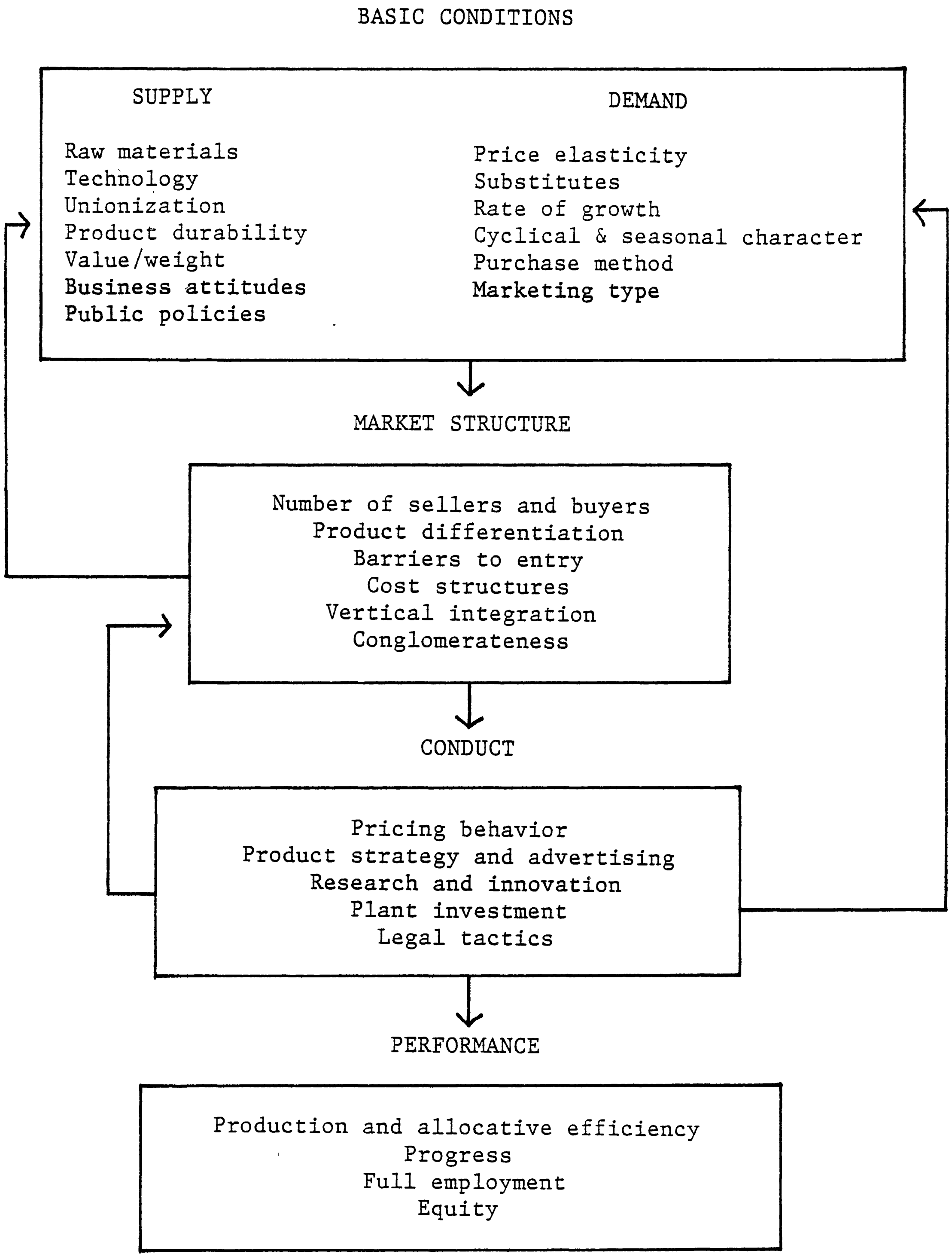

Figure 1. Scherer's Model of Industrial Organization Analysis

If demand and supply conditions are assumed uncontrollable by industry participants, then market structure, conduct, and performance become the important determinants of industrial organization.

One of the determinants of market structure is cost structures. Baumol, Panzar, and Willig (1982) proposed a model using the long-run average cost curve for firms in an industry to determine market structure of an industry. This model is illustrated in Figure 2. The long-run average cost curve declines over a wide quantity range and thereafter is relatively constant. Qmin is the minimum quantity a plant must operate at in order to realize the least possible cost. In other words, a plant operating at Qmin is the minimum efficient plant size.

The demand curve in Figure 2 represents the entire industry demand. The point of intersection between the industry demand curve and the long-run average cost curve is the total quantity produced by the industry. Number of participants in the industry is determined by dividing total industry output by the minimum efficient plant size. The minimum efficient plant size becomes a barrier to entry, i.e. plants smaller than Qmin would have significantly higher costs (Bain, 1968). Product differentiation, vertical integration, multiplant firms, and conglomerates can also be defined as barriers to entry (Bain, 1968). Market structure viewed in this conceptual framework is determined primarily by the nature of the long-run average cost curve.

Cost Theory

Cost functions incorporate the production function and fixed and variable costs of production (Doll and Orazem, 1978). The production function describes the rate at which resources are transformed into

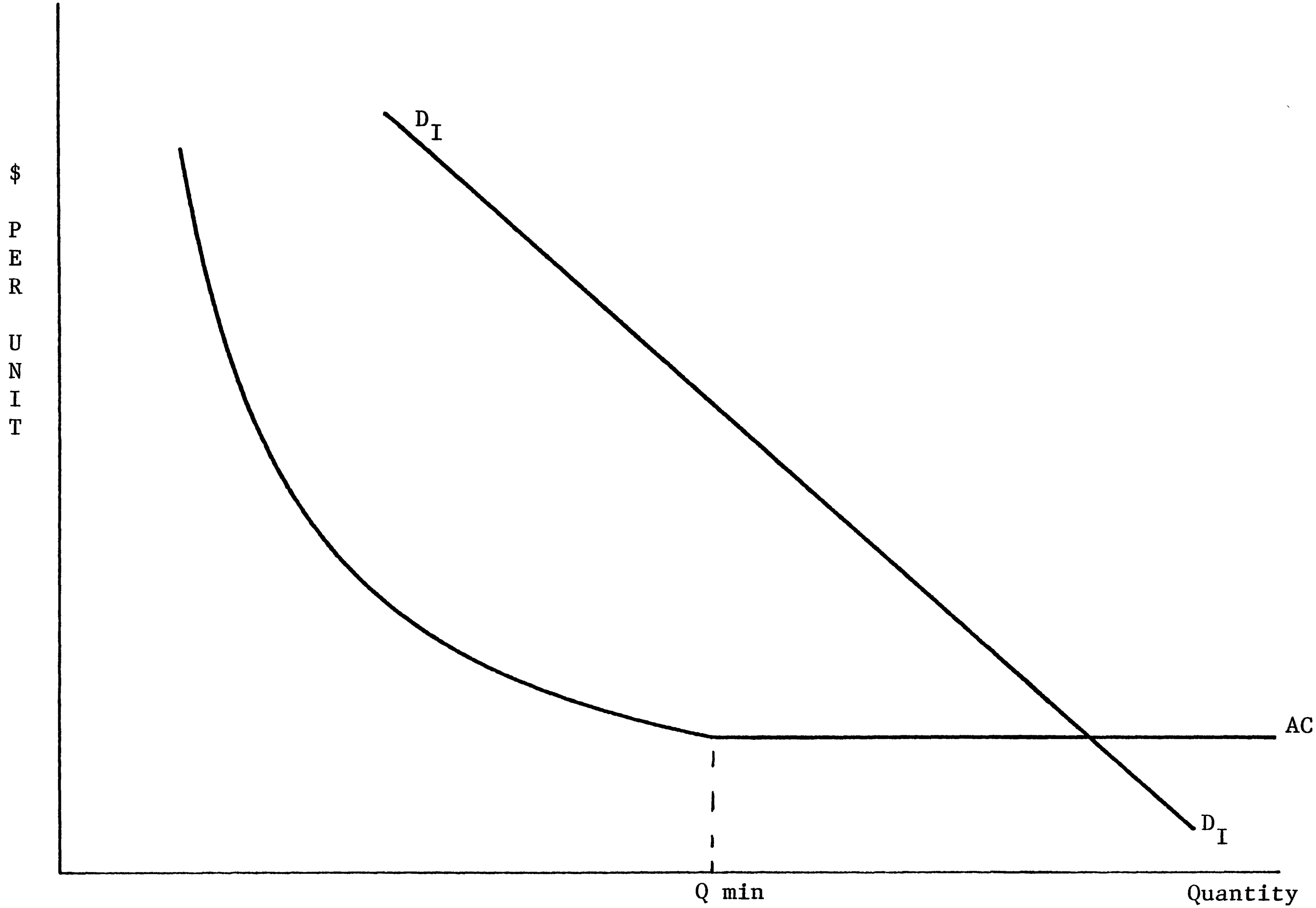

Figure 2. Baumol's Market Structure Model

products, i.e., technical efficiency. They express output as a function of input (Doll and Orazem, 1978). A manager is interested in the minimum cost point of production.

Cost functions represent the cost of fixed and variable inputs as functions of the amount of output (Doll and Orazem, 1978). Thus, they incorporate input prices into the decision of where to operate at, the minimum efficient level of output, or what is the minimum efficient plant size, i.e., economic efficiency.

Input costs are input quantities multiplied by input prices. Therefore, cost functions and production functions are inversely related to each other (Doll and Orazem, 1978).

Cost functions can be derived from the production function. The producton function along with fixed costs and input prices are needed to derive all cost functions. An alternative to using production functions to estimate costs is to estimate cost functions directly. Collecting costs and output data for a large sample of similar firms will give a relationship between costs and output.

Short-Run Costs

Short-run costs depend on the physical conditions of production and unit prices of inputs associated with each level of output (Gould and Ferguson, 1980). An isoquant curve shows all possible combinations of inputs physically capable of producing a given level of output. An isocost curve represents all possible combinations of inputs for a fixed level of cost. The tangency point between an isoquant and isocost curve represents the technical and economically efficient (i.e., optimal) combination of inputs for a particular level of output.

In the short-run one or more factors of production are fixed. To increase quantity produced in the short-run, variable factors of production are used in larger amounts than the optimal combination with the fixed factor of production. This increases short-run total cost of production assuming production is to the right of the minimum cost point (Gould and Ferguson, 1980).

Short-run total cost is comprised of total fixed and total variable costs. Total fixed cost is the sum of all costs associated with the factors of production that are not varied during the production period (Doll and Orazem, 1978). Total variable cost is the sum of all costs associated with the factors of production which are varied during the production period. Mathematically, short-run total cost is:

$$TVC = \sum_{i=1}^{n} P_i Q_i \tag{2.1}$$

where:

TVC = total variable cost

P_i = price of the ith variable input

Q_i = quantity of the ith variable input

$$TFC = \sum_{i=1}^{n} C_i \tag{2.2}$$

where:

TFC = total fixed cost

C_i = cost of the ith fixed variable

$$SRTC = TVC + TFC \tag{2.3}$$

where:

SRTC = short-run total cost

Average fixed cost is total fixed cost divided by output and average variable cost is total variable cost divided by output (Gould and Ferguson, 1980). Thus, short-run average total cost is the sum of average total fixed cost and average total variable cost. Mathematically, short-run average total cost is:

$$AFC = TFC/Q \qquad (2.4)$$

where:

AFC = average fixed cost

TFC = total fixed cost

Q = quantity of output

$$AVC = TVC/Q \qquad (2.5)$$

where:

AVC = average variable cost

TVC = total variable cost

Q = quantity of output

$$SRATC = AFC + AVC \qquad (2.6)$$

where:

SRATC = short-run average total cost

The short-run marginal cost is the addition to short-run total cost attributable to the addition of one unit of output (Gould and Ferguson, 1980). Mathematically marginal cost is:

$$MC = \Delta TVC/\Delta Q \qquad (2.7)$$

where:

MC = marginal cost

TVC = total variable cost

Q = quantity of output

Δ = change

Just as total cost is inversely related to the production function so are average variable and marginal costs inversely related to average product (total product divided by output) and marginal product (change in total product for a one-unit change in output), respectively. This can be shown as follows:

$$AVC = TVC/Q = P * VI/Q \quad (2.8)$$

$$AP = Q/VI \quad (2.9)$$

$$AVC = P * 1/AP \quad (2.10)$$

where:

AVC = average variable cost

TVC = total variable cost

Q = quantity of output

P = price of input

VI = units of variable input

AP = average product

$$MC = \Delta TVC/\Delta Q = P * \Delta VI/\Delta Q \quad (2.11)$$

$$MP = Q/VI \quad (2.12)$$

$$MC = p * 1/MP \quad (2.13)$$

where:

MC = marginal cost

TVC = total variable cost

Q = quantity of output

P = price of input

VI = units of variable input

MP = marginal product

Δ = change

Long-Run Costs

The long-run is a time period long enough for all inputs to be variable (Gould and Ferguson, 1980). The long-run may be considered a planning period in which all possible short-run situations are feasible. Long-run average cost is a locus of points representing the least unit cost of producing the corresponding output (Gould and Ferguson, 1980). The long-run marginal cost curve shows the minimum amount by which cost is increased when output is expanded and the maximum amount that can be saved when output is reduced (Gould and Ferguson, 1980).

Long-run and short-run average costs can also be derived from the production function. The expansion path, which is the locus of all tangency points between the isoquants and isocosts, corresponds to the tangency points between long-run and short-run average costs.

Bain (1968) discusses four possible shapes for the long-run average cost curve. Figure 3 illustrates the traditional U-shaped long-run average cost curve. As plant size becomes larger average cost decreases up to a unique plant size. Thereafter, average cost increases as plant size increases. A U-shaped long-run average cost curve implies all plants in an industry would be the same size in order to minimize costs. Empirical evidence suggests a unique minimum cost plant size is uncommon (Bain, 1968).

Figure 4 illustrates a long-run average cost curve that decreases indefinitely. This is the natural monopoly case. Industries where fixed costs are a large proportion of total costs may be examples of natural monopolies.

Figure 5 illustrates a long-run average cost curve that reaches a minimum cost plant size and remains at a constant cost thereafter. This long-run average cost curve suggests an industry could have a range of plant sizes that are minimum cost. The fourth possible shape for the long-run average cost curve could be a curve identical to the one in

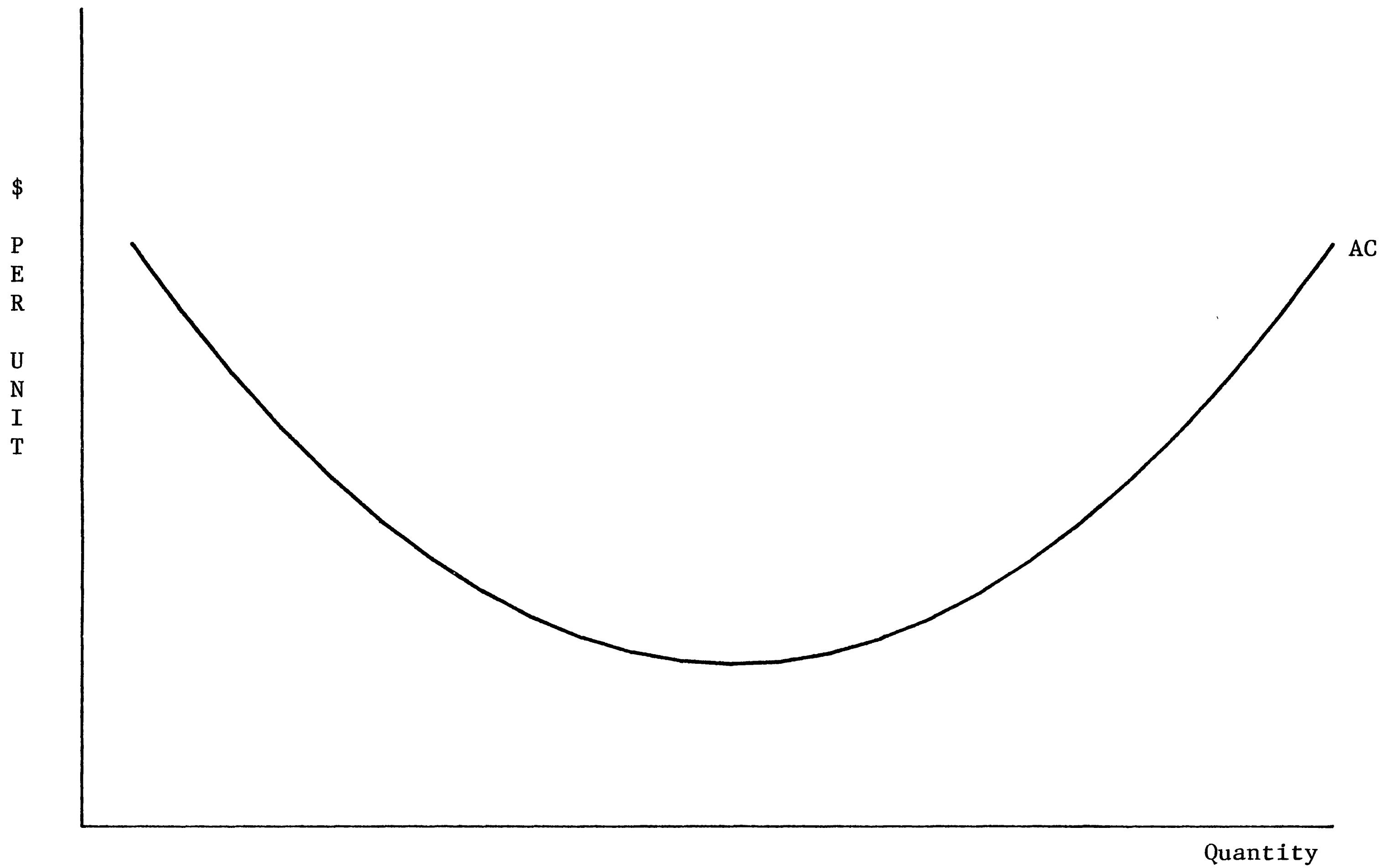

Figure 3. U-Shaped Long Run Average Cost Curve

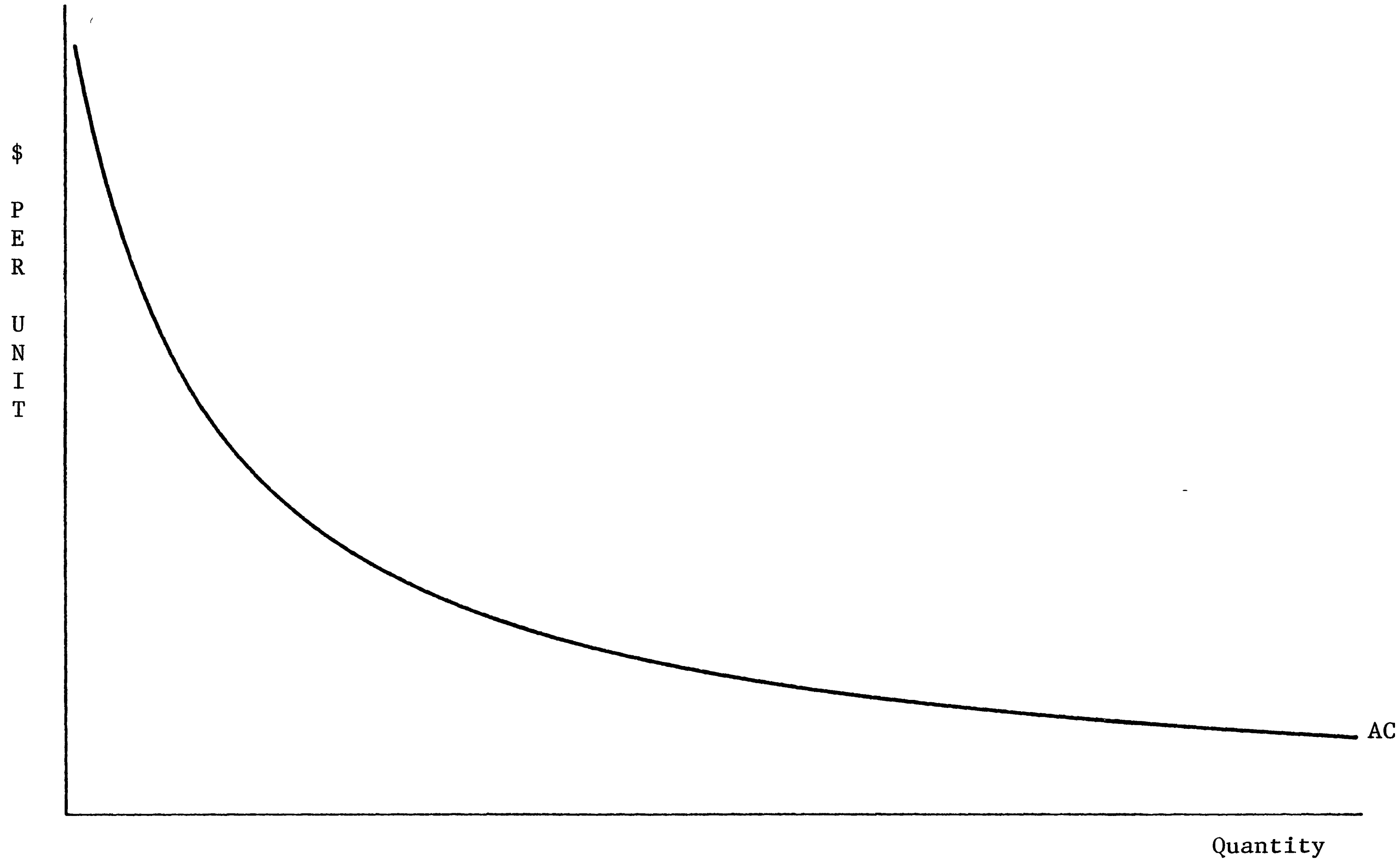

Figure 4. Infinitely Decreasing Long Run Average Cost Curve

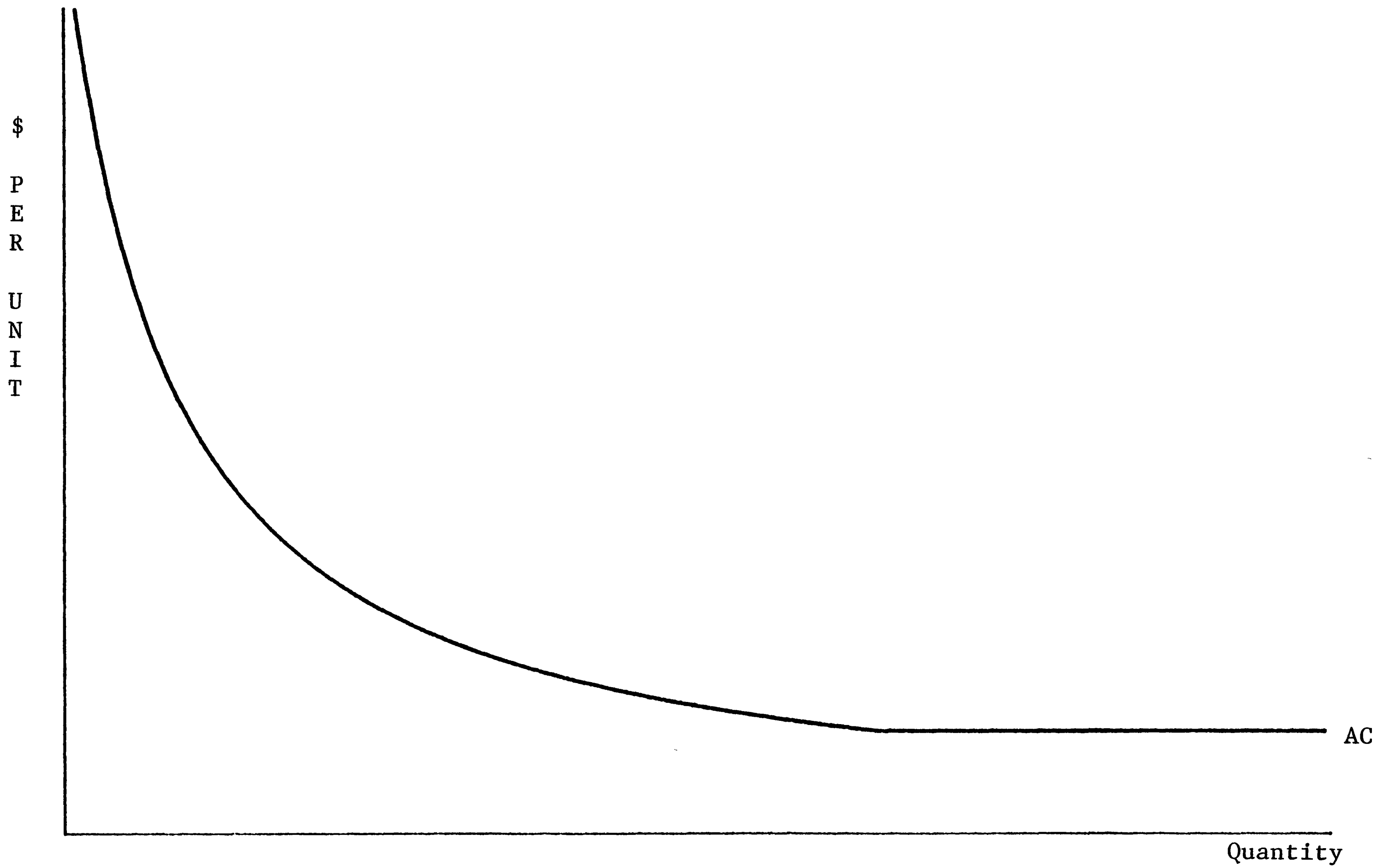

Figure 5. Industrial Organization Long Run Average Cost Curve

Figure 5, except it may turn up at a very large plant size. Long-run average cost curves that have been empirically estimated fit the pattern of Figure 5 (Bain, 1968).

Market Structure Framework

Bain (1968), Sherer (1980), and Sherman (1974) define an oligopoly as an industry where two or more sellers in the industry have a large enough market share, such that a small proportional increase in one seller's volume of sales (at the expense of other sellers in the industry) will result in a noticeable proportional decrease in sales by other sellers. Gould and Ferguson (1980) state the following assumptions for analytical convenience in the oligopoly market structure framework: (1) products in an oligopoly market are homogeneous; (2) oligopolistic firms purchase inputs in perfectly competitive markets; and (3) firms behave independently even though they are interdependent in the relevant product and geographic market.

Sales Maximization as a Management Objective

Baumol (1982) and Sherer (1980) have suggested profit maximization may not be the most appropriate management objective in an oligopolistic industry. Some features of oligopolistic behavior such as raising prices to cover fixed cost increases or the existence of firms larger than the minimum optimal size are not explained by the profit maximization management objective (Baumol, 1967). Baumol (1967) suggests sales or revenue maximization may be a more appropriate management objective.

Baumol's (1967) model of revenue maximization is:

$$\text{Maximize } R = R(X,S) \tag{2.14}$$

$$\text{subject to: } \pi \geq \pi_o$$

$$X,S \geq 0$$

where:

$R = P * X$ = total revenue or sales

X = output

P = price of output

S = general outlay on sales promotion or advertising

$\pi = (1-t)\ (R-C-S-T)$ = profit

$C = C(X)$ = total production cost

t = profit tax rate

T = any lump-sum tax

π_o = minimum acceptable profit

In the steer and heifer slaughter industry, products (i.e. primarily beef carcasses, primal custs, and boxed beef) are homogeneous so little or no outlay on sales promotion or advertising is necessary.

Modifying Baumol's (1967) model slightly results in a possible sales maximization model for the steer and heifer slaughter industry:

$$\text{Maximize } R = R(X) \tag{2.15}$$

$$\text{subject to: } \pi \geq 0$$

$$X \geq 0$$

where all variables are defined as above except $\pi = (1-t)\ (R-C-T)$ = profit.

A comparison between the profit maximization and sales maximization models is illustrated in Figure 6. The sales maximizer would produce where $\partial R/\partial X = 0$ shown as X_R. Thus the sales maximizer would forego some amount of profit to prdouce more output than the profit maximizer producing where $\partial \pi/\partial X = 0$ shown as X_m.

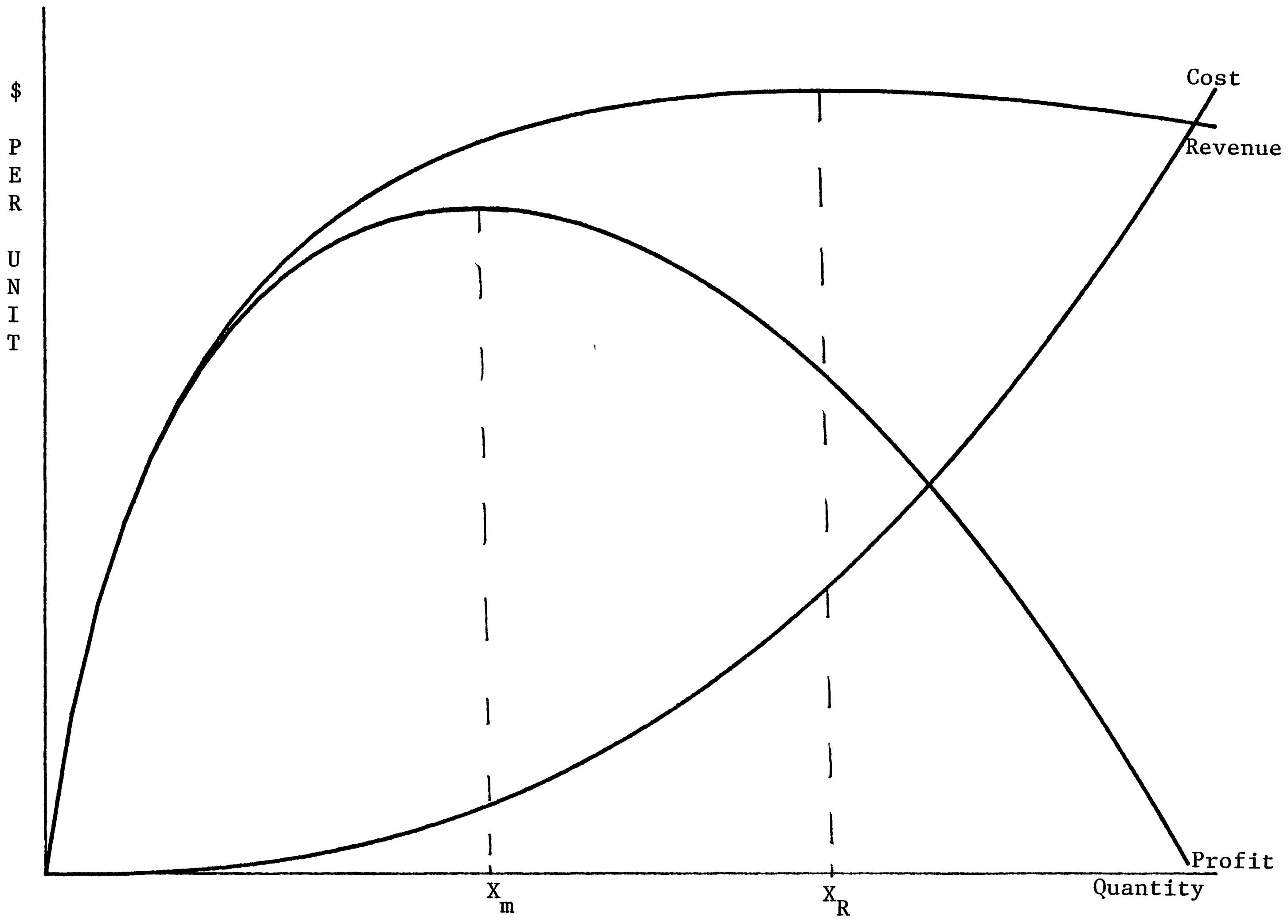

Figure 6. Comparison of Profit Maximization and Revenue Maximization

Therefore, in an industry where firms are sales maximizers, one would expect plants to be larger than if firms were profit maximizers given the same cost function. In industries where fixed costs are high relative to variable costs, large size plants are able to spread fixed costs over more total units of output thus lowering production costs. In industries with high fixed costs and where labor contracts prevent layoffs or guarantee a minimum number of hours per week, the production level will be far beyond the point of profit maximization (Raup, 1969).

Plants with high fixed costs will increase variable costs by operating to the right of the profit maximization point. Average fixed cost will decline as units of output are increased. As long as the decline in average fixed cost is greater than the increase in average variable cost, average total cost declines as units of output increases.

In 1983 the meatpacking industry was 70 percent unionized (Anderson, 1984). Labor union contracts in the meatpacking industry commonly have a weekly guarantee of either 32, 36, or 40 hours based on a Monday through Friday eight-hour-per-day work week (United Food and Commercial Workers, 1984). Time-and-a-half is paid for Saturday's and anything over eight hours on Monday through Friday. There is usually a 10 to 12 cents per hour premium paid to night shift workers. Fringe benefits include health and life insurance and a guarantee the plant will not close for a specified length of time (United Food and Commercial Workers, 1984). Labor costs can be considered a fixed cost Monday through Friday for the length of the contract. To minimize labor costs for this time period, maximum units of output need to be produced.

Management has more control over some variables in Baumol's (1967) model than others. Packers and Stockyards Program (1978) reported that about 70 percent of beef carcasses are formula priced off a future reported price, leaving the seller with little control over the price of the output. Taxes are set by the political system. Production costs and output are the variables management has the ability to change.

In the steer and heifer slaughter industry production costs can be divided into procurement costs and processing costs. Ward (1984) reported results supporting the contention that packers buy cattle at the market price and no packer pays significantly more or less for the same quality cattle. Therefore, plant processing costs (slaughter and fabrication) are the costs management can change in order to minimize cost and maintain a minimum profit level or to minimize losses.

Scherer (1980) suggests that increasing production hours in the short-run will reduce costs. Management has the flexibility to increase hours worked per shift, days worked per week, and shifts worked per day to decrease average cost per unit of output. Operating at less than 100 percent plant capacity will increase average cost per unit of output, i.e., there are less units of output over which to spread fixed costs. Therefore, in the short-run, the important economic phenomenon is economies of size.

In the long-run, economies of scale are important in minimizing average cost per unit of output. Economies of scale result from mass production techniques such as: (1) specialization of labor, i.e., applying labor units to specific narrow jobs; (3) use of specialized machinery; and (3) specialization of management and supervisory personnel (Bain, 1968). Economies of scale are important in an industry when the minimum efficient long-run plant size is a large enough fraction of total industry output, such that an additional minimum efficient plant would significantly reduce market price (Bain, 1968).

CHAPTER III

ANALYTICAL PROCEDURES

Methods of Cost Analysis

The following discussion outlines three cost estimation approaches. Data sources, assumptions, advantages, disadvantages, biases, and appropriate use of each approach are discussed.

Statistical Cost Analysis

Statistical cost analysis uses data from firms in operation to estimate the relationship between cost and output. The equation AC=f(q) where AC is average cost and q the rate of output is estimated by regression analysis in the statistical cost approach. The functional form (f) may be linear, quadratic, or more complex. This approach is straighforward to evaluate since it uses standard statistical techniques (Sawyer, 1981).

Statistical cost analysis has several disadvantages. Observations on average cost and quantity should be drawn from firms producing a homogeneous product (Sawyer, 1981). Frequently, a product varies among firms and average costs are not directly comparable across firms.

A second drawback is the average cost curve estimated by the statistical cost method is not the average cost curve economists refer to (Sawyer, 1981). The statistical cost curve is fitted by regression to the data thus some costs are above the cost curve and others are below the curve. Economists assume a cost curve under full technical efficiency, i.e., all firms would have costs above or on the cost curve. However, if the main objective is to identify the minimum efficient plant size(s) or the shape of the average cost curve then the statistical cost analysis will provide a good approximation (Sawyer, 1981).

The third disadvantage relates to the assumption that firms minimize costs. Data collected from firms in operation will cluster on the downward sloping and flat portion of the average cost curve. Rarely are average costs observed on the upward sloping portion of the average cost curve. The statistical average cost curve will imply increasing returns to scale, i.e., average costs continue to decline as plant size becomes larger, when in fact the average cost curve may be constant or turn up at large outputs (Sawyer, 1981).

Cross section data, such as average costs across firms for a given time period, is subject to what Mansfield (1975) refers to as regression fallacy. The actual and expected output level of firms differs because the factors influencing output are only partly under control of the firm. Firms at actual high output levels will have lower unit costs than firms at actual low output levels. Also, the observed cost of producing actual output levels will differ from the minimum cost of producing expected output levels. Thus, cross section studies are generally biased (Mansfield, 1975). Observations combined from low and high output plants will generate a downward sloping average cost curve.

Another problem is cost components being homogeneous among firms. Managerial and accounting practices differ among firms. Comparing costs that are calculated differently will lead to biased results (Sawyer, 1981).

Statistical cost analysis has a bias towards finding constant or declining average costs. However, one of its advantages is that it draws upon the operating experience of firms in the industry (Sawyer, 1981).

Economic-Engineering Approach

The economic-engineering approach breaks down the production process into elementary details. Physical input-output relationships are obtained at each elementary level and used to synthesize model plants for various levels of output (Logan and King, 1962). Physical relationships are converted into cost-volume relations to determine the long-run cost function. The researcher combines various cost components to arrive at a total cost for the entire production process.

One advantage of the economic-engineering approach is the assumptions underlying the calculation of costs are set by the researcher and can be varied to see how costs are affected by different accounting methods (Sawyer, 1981). A serious problem with the economic-engineering approach is input-output relationships are based on the latest technology reflecting only costs of new plants and excluding technically outmoded plants from the analysis (Sawyer, 1981). Another problem is if the proportions in which the cost components are combined to arrive at a total cost are not feasible in practice then the analysis is biased.

The results from the economic-engineering approach generally find increasing returns to scale, i.e., when all inputs are increased proportionally, output increases by a greater amount (Sawyer, 1981). The increasing returns to scale finding is partially due to omitting costs that are difficult to measure and such costs are generally increasing in nature.

Survivor Technique

The survivor technique looks at changes in the size distribution of plants within an industry over time to see what plant sizes are increasing their market share (Shepherd, 1967). Size groups increasing their market share are identified as efficient plant sizes. The survivor technique reflects all functions performed by firms, i.e., including management which is difficult to measure (Sawyer, 1981). Data collection is relatively simple, requirements being only size class statistics on number of plants and share of output. Thus, this technique can be applied to a large range of industries.

Shepherd (1967) identified several limitations of the survivor technique. The technique is descriptive rather than normative, describing the range of efficient plant sizes instead of what should be efficient. Secondly, survivor trends include costs internal and external to the plant so trends cannot be attributed to a particular sources. A range of efficient sizes are identified but within this range no differentiation can be made. All plants are assumed to be alike and operating in a common environment. Finally, the survivor technique does not explain a constant distribution over time but only recognizes changes in market share, thus ignoring stability over time as a criterion for efficiency.

Method of Cost Analysis for This Study

The primary objective of this study is to develop short-run and long-run average cost models for firms currently operating in the steer and heifer processing industry. The statistical cost analysis technique uses data from firms operating in the industry, making it the most appropriate technique given the objective.

Data Source

Average cost estimates were collected from key management personnel in firms operating in the steer and heifer slaughter industry. In Chapter II, it was contended that prices paid for cattle and prices received for carcasses of the same quality were not significantly different among firms. Thus, operating costs are the primary determinants of profit or losses. Firms in the steer and heifer slaughter industry are hesitant to release their operating costs because competitiveness is based on these costs.

Therefore, a survey questionnaire was designed to provide a descriptive picture of average slaughter and fabrication costs under differing hypothetical operating conditions. The mail survey instrument consisted of two parts, one for steer and heifer slaughter operations (Appendix A) and one for steer and heifer fabrication operations (Appendix B). The questionnaire was developed and tested with the help of several industry participants including the Packers and Stockyards Administration and the American Meat Institute.

There were two versions of each of the slaughter and fabrication questionnaires. One version was developed for plant sizes between 52,000 and 301,600 head processed per year and the other version for plants with capacity between 426,400 and 676,000 head processed per year. Plant size is defined as a head per hour rate operating a one, 8-hour shift per day, 5 days per week, 260 days per year. This volume of output is in turn defined as 100 percent capacity for a plant size. From a priori knowledge of the steer and heifer slaughter industry, 52,000 head processed per year was selected as the smallest plant size to consider. The remaining four size groups were selected at equal intervals from each other. The smallest three size groups were included on one version of the questionnaire, while the largest three size groups were included on the other version.

The survey instrument consisted of three open-ended questions and a section asking respondents to estimate average costs per head slaughtered or fabricated under different operating conditions. The open-ended questions asked respondents' opinions about what contributed to improved efficiency in the meatpacking industry in the past 10 to 20 years, market niches in the meatpacking industry, and size of plant that is currently cost competitive and one that will still be cost competitive 5 years from now for plants slaughtering or fabricating. Responses from those questions were not used in this study.

The second section gives a base situation for a plant slaughtering or fabricating beef. The base situation specifies a year in which the plant was built, operating hours per shift, days per week, and shifts per day for the plant, and base wage rate and fringe benefit package for union laborers. Each respondent estimated average cost per head for three different plant sizes under the base situation. Then respondents estimated average costs per head based on changes in operating conditions for three different plant sizes. Operating conditions that changed one at a time from the base situation were hours worked per shift, days worked per week, number of shifts per day, and percent of capacity utilized. The wage rate per hour for union laborers was lower for the fabrication base situation because of information provided by industry sources. Otherwise, slaughter and fabrication surveys were the same.

Questionnaires were mailed to all slaughter operations processing 50,000 head per year or more and all known fabrication operations based on a mailing list compiled from industry sources. Thirty-two slaughter and fabrication operations, 24 slaughter operations, and 29 fabrication operations received the questionnaire. One follow-up mailing went to nonrespondents. All nonrespondents from the two mailings were contacted by phone and were asked to participate in the survey, though several declined.

Response was low as expected due to the sensitivity of firms to provide cost data, even for hypothetical plants. Also, some managers of small plants indicated they did not know what costs were for the given plant sizes and operating conditions. Eight small slaughter operations, two large slaughter operations, one small fabrication operation, and seven large slaughter and fabrication operations responded. Responses from operations that slaughter and fabricate at the same location were not differentiated from responses from operations slaughtering or fabricating only. As estimated 40 to 50 percent of the total steer and heifer slaughter and fabrication industry was represented by respondents from the mail survey.

One response from a small slaughter operation had average cost estimates considerably lower than average cost estimates from other small slaughter operation respondents, however, lower than average costs reported by Cothern et al. (1978) and lower than average costs reported in articles appearing in Meat Industry and Business Week. Thus, these average cost estimates were treated as outliers and deleted from the analysis.

Similarily, average cost estimates from the sole small fabrication operation responding to the survey had unusually low average cost estimates, compared with quoted average fabrication costs reported in Meat Industry. Thus, average cost estimates from that respondent were also considered outliers and were deleted from the analysis.

Method and Model Description

Factors affecting average costs per head slaughtered or fabricated, such as size of plant, hours worked per shift, days worked per week, shifts worked per day, and capacity utilized were treated as binary variables. A binary variable can take on one of two values, zero or one, or it can be conventionally scaled, i.e., a certain number of hours worked per week would be assigned a unit value for a binary variable (Madsen and Liu, 1971).

The statistical model is the general linear model when binary variables are used as independent variables. The general linear model is:

$$Y = \beta_o + \sum_{i=1}^{n} \beta_i X_i + \mu \qquad (3.1)$$

where:

Y = dependent variable

β_i = coefficient for the ith independent binary variable

X_i = the ith independent binary variable

μ = disturbance term

Assumptions for the general linear model are: (1) the dependent variable is a linear function of a specific set of independent variables plus a disturbance term; (2) the disturbances have uniform variance, are uncorrelated, and have expected value of zero; (3) observations on independent variables are fixed in repeated samples; (4) no exact linear relationships exist between independent variables; and (5) there are more observations than independent variables (Kennedy, 1983).

Generally average cost functions are quadratic, but by partitioning the scale of a continuous variable into small intervals and defining a set of binary variables on each interval, an unbiased approximation of the nonlinear relationship is made (Suits, 1957). Each average cost response on the questionnaires in Appendices A and B was associated with a unique quantity, thus the curvilinear relationship between average costs and quantity can be estimated directly. Estimating a function in two different ways allows a comparison to be made between estimation techniques.

Variable Identification

Variables considered were based on a priori knowledge of industry operating conditions and input from individual sources. They were:

1. Plant size

   X11 = 25 head/hour or 200 head/day processed

   X12 = 85 head/hour or 680 head/day processed

   X13 = 145 head/hour or 1160 head/day processed

   X14 = 205 head/hour or 1640 head/day processed

   X15 = 265 head/hour or 2120 head/day processed

   X16 = 325 head/hour or 2600 head/day processed

2. Hours worked per shift

   X21 = 8 hours per shift

   X22 = 9 hours per shift

   X23 = 10 hours per shift

3. Days worked per week

X31 = 5 days per week

X32 = 6 days per week

4. Shifts worked per day

X41 = One 8-hour shift per day

X42 = Two 8-hour shifts per day

5. Capacity utilized

X51 = 100 percent of plant capacity

X52 = 90 percent of plant capacity

X53 = 80 percent of plant capacity

Days worked per week and capacity utilized variables were combined into one variable. One hundred percent capacity utilized was equivalent to 8 hours per shift for 5 or 6 days per week. Ninety percent capacity utilized was the same as a 4-day, 9-hour shift work week, and 80 percent capacity utilized was equivalent to a 4-day, 8-hour shift work week. Thus, days worked per week, and capacity utilized variables convert into the following:

6. Capacity utilized converted to days worked per week and hours worked per shift

X61 = 5 days per week, 8 hours per shift

X62 = 6 days per week, 8 hours per shift

X63 = 4 days per week, 9 hours per shift

X64 = 4 days per week, 8 hours per shift

Hours worked per shift, days worked per week, shifts worked per day, and capacity utilized variables can be combined into a single variable, i.e., hours worked per week. One-, 8-, 9-, or 10-hour shifts, 5 days per week, and 100 percent capacity utilized are equivalent to 40, 45 or

50 hours worked per week, respectively. A one, 8-hour shift, 6 days per week, and 100 percent capacity utilized is the same as 48 hours worked per week. Ninety and 90 percent capacity utilized are equivalent to 36 and 32 hours worked per week. Two, 8-hour shifts per day and 100 percent capacity utilized are the same as 80 hours worked per week. Thus, redefined hours worked per week were:

7. Hours worked per shift, days worked per week, shifts worked per day, and capacity utilized converted to hours worked per week

X71 = 40 hours worked per week

X72 = 45 hours worked per week

X73 = 50 hours worked per week

X74 = 48 hours worked per week

X75 = 36 hours worked per week

X76 = 32 hours worked per week

X77 = 80 hours worked per week

All variables initially defined can be associated with a quantity of head processed per year. The head processed per year equivalent to plant operating condition variables by plant size are reported in Table 2. The quantity variables were:

8. All binary variables converted to a quantity value

X81 = quantity of steers and heifers processed per year

X82 = X81 squared

Equations to be Estimated

The following equations were estimated. Equations 3.2, 3.4, and 3.6 provide estimates for long-run average costs; equations 3.3, 3.5, and 3.7 provide estimates for short-run average costs. Equation 3.8 provides an

Table 2. Plant Operating Condition Variables (i.e. Hours Worked Per Shift, Days Worked Per Week, Shifts Worked Per Day, and Capacity Utilized) Converted to Head Processed Per Year By Plant Size

	Plant Size					
	25 hd/hr	85 hd/hr	145 hd/hr	205 hd/hr	265 hr/hr	325 hd/hr
	(Head Processed Per Year)					
Base Situation (One-8 hour shift, 5 days, 100% capacity)	52,000	176,800	301,600	426,400	551,200	676,000
9 hours per shift	58,500	198,900	339,300	479,700	620,100	760,500
10 hours per shift	65,000	221,000	377,000	533,000	689,000	845,000
6 days per week	62,400	212,160	361,920	511,680	661,440	811,200
2 shifts per day	104,000	353,600	603,200	852,800	1,102,400	1,352,000
90% capacity utilized	46,800	159,120	271,440	383,760	496,080	608,400
80% capacity utilized	41,600	141,440	241,280	341,120	440,960	540,800

estimate for both long-run and short-run average costs when estimated for all plant sizes and by plant size, respectively.

Average cost/head =

$$\beta_o = \sum_{i=1}^{6} \beta_{1i}X_{1i} + \sum_{i=1}^{3} \beta_{2i}X_{2i} + \sum_{i=1}^{2} \beta_{3i}X_{3i} + \sum_{i=1}^{2} \beta_{4i}X_{4i} + \sum_{i=1}^{3} \beta_{5i}X_{5i} + \mu \qquad (3.2)$$

Average cost/head =

$$\beta_o + \sum_{i=1}^{3} \beta_{2i}X_{2i} + \sum_{i=1}^{2} \beta_{3i}X_{3i} + \sum_{i=1}^{2} \beta_{4i}X_{4i} + \sum_{i=1}^{3} \beta_{5i}X_{5i} + \mu \qquad (3.3)$$

Average cost/head =

$$\beta_o + \sum_{i=1}^{6} \beta_{1i}X_{1i} + \sum_{i=1}^{2} \beta_{3i}X_{3i} + \sum_{i=1}^{2} \beta_{4i}X_{4i} \sum_{i=1}^{4} \beta_{6i}X_{6i} + \mu \qquad (3.4)$$

Average cost/head =

$$\beta_o + \sum_{i=1}^{3} \beta_{2i}X_{2i} + \sum_{i=1}^{2} \beta_{4i}X_{4i} + \sum_{i=1}^{4} \beta_{6i}X_{6i} + \mu \qquad (3.5)$$

Average cost/head =

$$\beta_o + \sum_{i=1}^{6} \beta_{1i}X_{1i} + \sum_{i=1}^{7} \beta_{7i}X_{7i} + \mu \qquad (3.6)$$

Average cost/head =

$$\beta_o + \sum_{i=1}^{7} \beta_{7i}X_{ui} + \mu \qquad (3.7)$$

Average cost/head =

$$\beta_o + \sum_{i=1}^{2} \beta_{8i}X_{8i} + \mu \qquad (3.8)$$

The above seven equations were estimated for slaughter and fabrication plants.

Multicollinearity

Multicollinearity is the existence of an approximate linear relationship among the independent variables (Kennedy, 1983). Multicollinearity could arise for several reasons. The independent variables may share a common time trend, vary together because the data were not collected from a wide enough base, or there could exist some approximate relationship among some of the regressors. Economists are faced with multicollinearity often because they do not collect data from controlled experiments that are designed to eliminate correlation among the independent variables (Kennedy, 1983).

When multicollinearity exists, ordinary least squares estimators remain unbiased. However, the variance of parameter estimates of the collinear variables are large (Kennedy, 1983). Large variances are caused by insufficient independent variation in a variable to calculate with confidence the effect it has on the dependent variable (Kennedy, 1983). Large variances mean parameter estimates are not precise and hypothesis testing is not powerful. The individual hypothesis cannot be rejected for the parameter estimates that are collinear (Kennedy, 1983). However, the joint hypothesis that all parameter estimates that are collinear are equal to zero is rejected (Kennedy, 1983). The conclusion being that at least one of the variables is relevant.

Two tests for determining the degree of multicollinearity are suggested. First, if an independent variable known to influence the dependent variable has an insignificant estimated coefficient then multicollinearity is suspected. Second, the simple correlation coefficients between all pairs of independent variables can be calculated.

A high correlation coefficient value (i.e., .8 or .9) indicates the two independent variables to which it refers are highly correlated (Kennedy, 1983).

There are many ways to correct for multicollinearity. Some of the commonly used techniques are: (1) obtain more data; (2) transform the variables; (3) drop one of the collinear variables; or (4) use an extraneous estimate of the coefficient of one of the variables involved in the multicollinearity (Kennedy, 1983). Often, the degree of multicollinearity is minor so no correction is made (Kennedy, 1983).

The severity of the multicollinearity problem is left to the discretion of the researcher. Obtaining more data will only help to alleviate the problem if additional data does not contain multicollinearity. Variables creating multicollinearity problems can be eliminated by transforming the variables, or one of the collinear variables can be dropped from the model to be estimated. This procedure is effective as long as the true coefficient of the omitted variable is zero. Otherwise, a specification error is created causing the estimates of the parameters of the remaining variables to be biased. When an extraneous estimate is used for a coefficient it must be relevant (Kennedy, 1983).

The simple correlation coefficients were calculated between all pairs of independent variables. Among the variables--plant size, hours worked per shift, days worked per week, shifts worked per day and capacity utilized--the largest simple correlation coefficient was .67. When hours worked per shift, days worked per week, shifts worked per day, and capacity utilized were converted to hours worked per week, the largest simple correlation coefficient was .18. When quantity of steers and heifers processed per year and the square of this variable were used, the simple correlation coefficient was .95 for slaughter data and .98 for fabrication data. However, multicollinearity is expected between transformed variables and is unavoidable.

Heteroskedasticity

Kennedy (1983) defines heteroskedasticity as disturbances not all having a common variance. Larger independent variables tend to have larger variances of their respective disturbances (Kennedy, 1983). At higher levels of the independent variable there is more room to deviate from the regression line than at smaller levels. Measurement errors may also be greater at higher levels of the independent variables. Heteroskedasticity results in a greater variance of the parmaeter estimates (Kennedy, 1983). Prais and Houthakker (1955) did some pioneering work on family budget studies where they found the disturbance variance increased with family income. Now it is generally assumed that cross sectional data involving heterogenous units will hae heteroskedasticity. If one is examining a cross section of firms in an industry, there may be reason to believe that disturbance terms associated with very large firms will have larger variances than disturbance terms associated with smaller firms (Pindyck and Rubinfeld, 1981).

A model with heteroskedastic error disturbances assumes each error term ε_i is normally distributed with variance σ_i^2 that is not constant over observations (Pindyck and Rubinfeld, 1981). The ordinary least squares estimation procedure places more weight on the observations with large error variances than those with small error variances. The total sum of squared residuals will be minimized and this can best be accomplished by guaranteeing a good fit in the large variance portion of the data. The ordinary least squares parameter estimates are unbiased and consistent but they are not efficient, i.e., the variances of the estimated parameters are not the minimum variances (Pindyck and Rubinfeld, 1981).

As with multicollinearity there are no concrete rules for detecting heteroskedasticity, only a few rules of thumb. A common method of checking for heteroskedasticity is to plot the predicted values against the residuals to see if there is a pattern between the predicted values and the residuals. If there seems to be a pattern between the predicted values and residuals then a more formalized test can be made.

One such formalized test for heteroskedasticity, as outlined by Glejser (1969), is to regress the absolute value of the residuals on the predicted values. Heteroskedasticity is present if the intercept and slope are significantly different from zero or just the slope is significantly different from zero.

Generally, we do not know the nature of heteroskedasticity (Maddala, 1977). Prais and Houthakker (1955) considered a model where the variance is proportional to the square of the regression function, i.e., $\sigma_i^2 = \sigma^2(\beta_o+\beta_i X_i)^2$. To estimate this model, β_o and β_i are first estimated by ordinary least squares. Then all observations (both dependent and independent variables) are divided by the reciprocal of the predicted value for each observation. Using the weighted dependent and independent variables, parameters are then estimated by generalized least squares. The test for heteroskedasticity as outlined by Glejser (1969) can be used to see if the weighted model has been corrected for heteroskedasticity. If not, the above procedure is repeated until convergence is attained.

The predicted values plotted against the residuals in this study showed an upward trend for slaughter and fabrication data on all models considered. The test outlined by Glejser (1969) showed the intercept and slope were significantly different from zero for the slaughter data but neither the intercept nor slope were significantly different from zero for the fabrication data. The Glejser (1969) test had the same results for all models estimated.

Pindyck and Rubinfeld (1981) conclude the model considered by Prais and Houthakker (1955) is an appropriate correction for heteroskedasticity when the intercept and the slope from the Glejser test are both significantly different from zero. The slaughter observations on the dependent and independent variables were weighted by one over the predicted value obtained from the ordinary least squares model. Now parameter estimates using the weighted variables were estimated by generalized least squares. Heteroskedasticity was checked by using the Glejser test on the predicted values and residuals from the weighted model. The slope and intercept were significantly different from zero so the correction procedure was iterated again. The parameter estimates and parameter variances changed very little indicating the degree of heteroskedasticity was not severe. Thus, no correction for heteroskedasticity was made.

CHAPTER IV

RESULTS

This chapter presents long-run and short-run average cost estimates for slaughter and fabrication using linear binary variable (LBV), quadratic, and logarithmic functional forms. Long-run refers to average cost per head estimates across plant sizes and plant operating conditions. Short-run refers to average cost per head estimates across plant operating conditions within each plant size.

Linear Binary Variable Functional Form

Binary variables (X_{1i} - X_{5i}) defined in Chapter III were used to estimate a linear equation for long-run and short-run average costs per head.

Slaughter

Results from the LBV slaughter cost model are reported in Table 3. All but one variable (i.e., 9 hours per shift) were significant in explaining the variation in average cost per head and the signs on the estimated parameters were consistent with economic theory.

The intercept represents average cost per head for a plant of size 25 head per hour, operating 8 hours per shift, 5 days per week, 1 shift per day, and at 100 percent capacity. Parameter estimates on all other binary variables (i.e., 85, 145, 205, 265, and 325 head per hour, 9 and

Table 3. Long Run Average Slaughter Cost Estimates From a Linear Binary Variable Regression Model

Independent Variable	$/Head	t-values
Intercept	40.71***[a]	48.12
Plant Size (X_{1i})		
25 hd/hr.	Base	
85 hd/hr.	-8.13***	-8.64
145 hd/hr.	-11.54***	-11.88
205 hd/hr.	-15.17***	-18.33
265 hd/hr.	-16.75***	-20.24
325 hd/hr.	-18.51***	-22.36
Hours/Shift (X_{2i})		
8 hours	Base	
9 hours	-.14	-.17
10 hours	-1.37*	-1.63
Days/Week (X_{3i})		
5 days	Base	
6 days	-1.36*	-1.63
Shifts/Day (X_{4i})		
1 shift	Base	
2 shifts	-3.36***	-4.07
Capacity Utilized (X_{5i})		
100 percent	Base	
90 percent	+2.96***	3.50
80 percent	+4.77***	5.63
R^2 = .732		
n = 285		

[a]Asterisks represent significance levels; ***.01, *.1.

10 hours per shift, 6 days per week, 2 shifts per day, and 90 and 80 percent capacity utilized) are interpreted as differences from the intercept. For example, a 145 head per hour plant size is estimated to reduce average cost per head by $11.54 (i.e., average cost per head would be $29.17).

Increases in plant size yield the largest reduction in average cost per head followed by changing one to two shifts per day, in the long-run LBV slaughter cost model. Reducing capacity utilized to 80 percent resutls in the greatest increase in average cost per head. The R^2 value indicates a relatively large portion of the variation in average cost per head is explained by the independent variables.

Traditionally, units of output have been used to explain variation in average cost in statistical cost estimation models (Sawyer, 1981). Using binary variables as independent variables, allows attributing differences in average cost per head to plant size and specific plant operating conditions. Each combination of binary variables is associated with a quantity processed per year (as presented in Chapter III, Table 2), thus variation in average cost is indirectly attributed to changes in number of head slaughtered per year.

Using quantity as the sole independent variable, generally results in an inverse relationship between quantity and average cost per head. Thus, as quantity increases average cost per head decreases. However, nothing can be concluded about how to increase quantity to get a maximum reduction in average cost per head. With binary variables representing plant size and plant operating conditions, a relationship between the binary variables and average cost per head is developed.

Short-run average cost estimates from the LBV model for plants slaughtering 25, 85, and 145 head per hour are presented in Table 4. Binary variables in the model explain relatively little of the differences in short-run average cost per head, as is evidenced by the insignificant t-values, and low R^2 values. This may suggest plants operating 145 head per hour or less cannot significantly lower average cost per head by increasing hours worked per shift, days worked per week, and shifts worked per day. In fact, working 9 and 10 hours per shift increases short-run average cost per day. This suggests average variable cost is higher than average fixed cost for plant sizes 145 head per hour or less. Also, decreasing capacity utilized does not increase average cost per head significantly except in 85 and 145 head per hour plant sizes. Thus, changing operating conditions in plants with a size of 145 head per hour or less generally does not affect average cost per head significantly. Variables such as labor wage rate, which affect average variable cost, may explain more of the variation in average cost per head in plants operating at 145 head per hour or less.

In plants operating at 205 head per hour or more, the binary variables explain significantly more of the variation in average cost per head than for the smaller plants (Table 5). Managers of large plants may be more aware of the relationship between average cost per head and plant operating conditions than managers of small plants. These results suggest plant sizes greater or equal to 205 head per hour need to operate 8 hours per shift, 6 days per week, 2 shifts per day, at 100 percent capacity to minimize short-run average slaughter cost per head. Any operating condition less than this will significantly increase short-run average slaughter cost per head.

Table 4. Short-Run Average Slaughter Cost Estimates From a Linear Binary Variable Regression Model for Plant Sizes 25 Hd/Hr., 85 Hd/Hr., and 145 Hd/Hr.

	Plant Size					
	25 Hd/Hr		85 Hd/Hr		145 Hd/Hr	
Independent Variable	$/head	t-value	$/head	t-value	$/head	t-value
Intercept	39.50***[a]	12.60	31.50***	12.62	28.00***	10.72
Hours/shift (X_{2i})						
8 hours	Base		Base		Base	
9 hours	+2.50	.50	+1.75	.44	+.63	.16
10 hours	+.75	.15	-.80	-.22	+.25	.06
Days/week (X_{3i})						
5 days	Base		Base		Base	
6 days	-1.83	-.41	+.10	.03	+.13	.03
Shifts/day (X_{4i})						
1 shift	Base		Base		Base	
2 shifts	-2.90	-.62	-3.50	-.99	-2.40	-.65
Capacity Utilized (X_{5i})						
100 percent	Base		Base		Base	
90 percent	+5.38	1.08	+5.00	1.27	+4.25	1.08
80 percent	+7.75	1.56	+7.75*	1.96	+7.25*	1.85
	R^2 = .206		R^2 = .282		R^2 = .253	
	n = 32		n = 33		n = 29	

[a]Asterisks represent significance levels; ***.01, *.1.

Table 5. Short-Run Average Slaughter Cost Estimates From a Linear Binary Variable Regression Model for Plant Sizes 205 Hd/Hr., 265 Hd/Hr., and 325 Hd/Hr.

	Plant Size					
	205 Hd/Hr		265 Hd/Hr		325 Hd/Hr	
Independent Variable	$/head	t-value	$/head	t-value	$/head	t-value
Intercept	26.39***[a]	44.72	24.78***	42.12	22.72***	34.32
Hours/Shift (X_{2i})						
8 hours	Base		Base		Base	
9 hours	-1.14	-1.36	-1.19	-1.44	-1.08	-1.16
10 hours	-2.41 ***	-2.90	-2.25***	-2.70	-1.94**	-2.08
Days/week (X_{3i})						
5 days	Base		Base		Base	
6 days	-1.83**	-2.20	-1.92**	-2.30	-1.72*	-1.84
Shifts/day (X_{4i})						
1 shift	Base		Base		Base	
2 shifts	-3.89***	-4.66	-3.83***	-4.61	-3.17***	-3.38
Capcaity Utilized (X_{5i})						
100 percent	Base		Base		Base	
90 percent	+1.78**	2.13	+1.81**	2.17	+2.11**	2.26
80 percent	+3.08***	3.70	+3.17***	3.81	+3.67***	3.92
	R^2 = .646 n = 62		R^2 = .647 n = 62		R^2 = .589 n = 62	

[a]Asterisks represent significance levels; ***.01, **.05, *.1.

Fabrication

Estimated long-run average costs from the LBV model are presented in Table 6. Signs on parameter estimates agree with economic theory. Two shifts per day significantly decreases average cost per head and 80 percent capacity utilized significantly increases average cost per head. There were fewer respondents and less variation among average cost estimates from which to estimate the long-run fabrication average cost model compared with the slaughter model.

Fabrication is a highly varied process compared with slaughter. A carcass can be fabricated several different ways, each with a unique cost. The selected binary variables did not account for differences in the way a carcass is fabricated, which may be significant in explaining average fabrication cost per head. That may explain the low R^2 value and insignificant t-values.

Short-run average fabrication cost estimates are presented in Table 7. The only significant variable in explaining the variation in average cost per head was 2 shifts per day and then only for plants of size 205 head per hour and 265 head per hour. Signs on the estimated parameters are consistent with economic theory. Data limitations, or not considering different ways a carcass can be fabricated, may explain the low R^2 values and insignificant t-values.

Binary Variables Redefined

Two variables (i.e., days worked per week and capacity utilized) were redefined into one variable called days worked per week and hours worked per shift (variable X_{6i} as described in Chapter III). The

Table 6. Long-Run Average Fabrication Cost Estimates From a Linear Binary Variable Regression Model

Independent Variable	$/Head	t-values
Intercept	50.27***[a]	34.30
Plant Size (X_{1i})		
205 hd/hr.	Base	
265 hd/hr.	-1.83	-1.53
325 hd/hr.	-3.47***	-2.90
Hours/Shift (X_{2i})		
8 hours	Base	
9 hours	-.80	-.44
10 hours	-1.54	-.84
Days/Week (X_{3i})		
5 days	Base	
6 days	-1.99	-1.09
Shifts/Day (X_{4i})		
1 shift	Base	
2 shifts	-5.04***	-2.76
Capacity Utilized (X_{5i})		
100 percent	Base	
90 percent	+.97	.53
80 percent	+3.16*	1.73
R^2 = .188		
n = 146		

[a]Asterisks represent significance levels; ***.01, *.1.

Table 7. Short-Run Average Fabrication Cost Estimates From a Linear Binary Variable Regression Model

Independent Variable	Plant Size 205 Hd/Hr $/head	205 Hd/Hr t-value	265 Hd/Hr $/head	265 Hd/Hr t-value	325 Hd/Hr $/head	325 Hd/Hr t-value
Intercept	50.41***[a]	19.97	48.48***	20.58	46.62***	21.94
Hours/shift (X_{2i})						
8 hours	Base		Base		Base	
9 hours	-.86	-.24	-.75	-.23	-.79	-.26
10 hours	-1.39	-.39	-1.65	-.50	-1.58	-.53
Days/week (X_{3i})						
5 days	Base		Base		Base	
6 days	-2.35	-.66	-1.89	-.57	-1.74	-.58
Shifts/day (X_{4i})						
1 shift	Base		Base		Base	
2 shifts	-5.78*	-1.62	-5.06*	-1.52	-4.28	-1.42
Capacity Utilized (X_{5i})						
100 percent	Base		Base		Base	
90 percent	+.78	.22	+.85	.26	+1 28	.43
80 percent	+3.35	.94	+2.99	.90	+3.13	1.04
	R^2 = .152		R^2 = .140		R^2 = .151	
	n = 48		n = 48		n = 48	

[a] Asterisks represent significance levels; ***.01, *.1.

LBV model was then re-estimated using the redefined variable in place of the original two variables days worked per week and capacity utilized. Parameter estimates were identical (for the days worked per week and hours worked per shift variable) to corresponding parameter estimates for days worked per week and capacity utilized variables for long-run and short-run slaughter cost models and both fabrication cost models. For example, the parameter estimate for 80 percent capacity utilized (Table 3) was the same as the parameter estimate for 4 days worked per week and 8 hours worked per shift.

Hours worked per shift, days worked per week, shifts worked per day, and capacity utilized variables were combined into a single variable called hours worked per week (variable X_{7i} as described in Chapter III). Again, parameter estimates were the same for the redefined variable (hours worked per week) as for the corresponding original variables (hours worked per shift, days worked per week, shifts worked per day, and capacity utilized), for long-run and short-run slaughter cost models and both fabrication cost models. For example, the parameter estimate for 2 shifts per day is the same as the parameter estimate for 80 hours worked per week. The re-estimated models were the same as models presented in Tables 3, 4, and 5 (slaughter) and Tables 6 and 7 (fabrication). Therefore, they were not reported.

Quadratic Functional Form

Binary variables were converted to an equivalent quantity processed per year value (as presented in Chapter III, Table 2).

Slaughter

Results of the quadratic long-run average slaughter cost model are presented in Table 8. Quantity and quantity squared significantly explained variation in average slaughter cost per head. The R^2 value is lower compared with the LBV estimated model. Thus, defining quantity according to plant operating conditions explained (e.g., as in the LBV model) more of the variation in average cost per head than using quantity slaughtered per year and quantity squared as the independent variables. Also, using only quantity variables as independent variables does not allow an interpretation as to how operating conditions decrease or increase average cost per head.

Table 9 presents quadratic short-run average slaughter cost estimates for 25, 85, and 145 head per hour size plants. Quantity squared is not significant for any of the three plant sizes. R^2 values are lower on the quadratic models compared with the corresponding LBV models. Low R^2 values may be attributed to a quadratic being an incorrect functional form to use in this particular case. Using a quadratic function implies average cost per head declines, reaches a minimum, and increases thereafter. This may be an unrealistic assumption, since average cost per head estimates decline over the entire quantity range considered unlike the textbook example of average cost curves.

Quadratic short-run average slaughter cost estimates for 205, 265, and 325 head per hour plant sizes are presented in Table 10. Parameter estimates are significant for all plant sizes. R^2 values are not different between corresponding quadratic and LBV models (.646 vs. .643, .647 vs. .645, and .589 vs. .583, respectively). More of the variation

Table 8. Long-Run Average Slaughter Cost Estimates From a Quadratic Annual Quantity Model

Independent Variable	$/Head	t-values
Intercept	42.02***[a]	61.76
Quantity of steers and heifers processed per year (X_{81})	-4.3×10^{-5}***	-17.79
Quantity of steers and heifers processed per year squared (X_{82})	$+2.0 \times 10^{11}$***	10.76
R^2 = .688		
n = 285		

[a] Asterisks represent significance levels; ***.01.

Table 9. Short-Run Average Slaughter Cost Estimates From a Quadratic Annual Quantity Model for Plant Sizes 25 Hd/Hr., 85 Hd/Hr., and 145 Hd/Hr.

	Plant Size					
	25 Hd/Hr		85 Hd/Hr		145 Hd/Hr	
Independent Variable	$/head	t-value	$/head	t-value	$/head	t-value
Intercept	73.96***[a]	3.84	63.68***	4.18	57.79***	3.86
Quantity of steers and heifers slaughtered per year (X_{81})	$-8.7\text{x}10^{-4}$*	-1.56	$-2.3\text{x}10^{-4}$*	-1.81	$-1.3\text{x}10^{-4}$*	-1.71
Quantity of steers and heifers slaughtered per year squared (X_{82})	$+4.9\text{x}10^{-9}$	1.33	$3.8\text{x}10^{-10}$	1.51	$1.3\text{x}10^{-10}$	1.46
	R^2 = .160 n = 32		R^2 = .243 n = 33		R^2 = .214 n = 29	

[a]Asterisks represent significance levels; ***.01, *.1.

Table 10. Short-Run Average Slaughter Cost Estimates From a Quadratic Annual Quantity Model for Plant Sizes 205 Hd/Hr., 265 Hd/Hr., and 325 Hd/Hr.

	Plant Size					
	205 Hd/Hr		265 Hd/Hr		325 Hd/Hr	
Independent Variable	$/head	t-value	$/head	t-value	$/head	t-value
Intercept	47.72***[a]	15.34	46.37***	14.95	46.14***	13.16
Quantity of steers and heifers slaughtered per year (X_{81})	$-6.9x10^{-5}$***	-6.27	$5.4x15^{-5}$***	-6.37	$-4.8x10^{-5}$***	-6.13
Quantity of steers and heifers slaughtered per year squared (X_{82})	$+4.6x10^{11}$***	5.18	$2.8x10^{11}$***	5.28	$2.1x10^{11}$***	5.22
	R^2 = .643		R^2 = .645		R^2 = .583	
	n = 62		n = 62		n = 62	

[a] Asterisks represent significance levels; ***.01.

in long-run average slaughter cost per head is explained in plants 205 head per hour or larger than in plants 145 head per hour or smaller, which was the case in the short-run estimated LBV models. This suggests managers of larger plants 205 head per hour or larger are more knowledgeable about what affects average cost per head than managers of smaller plants.

Fabrication

Results of the quadratic annual quantity model used to estimate long-run average fabrication cost are presented in Table 11. Parameter estimates are significant, however, R^2 values between LBV and quadratic models are not significantly different (.188 and .183, respectively). Due to the different ways a carcass can be fabricated, quantity may explain the variation in long-run average fabrication cost as well as plant operating conditions.

Table 12 presents quadratic short-run average cost estimates for fabrication models. Quantity and quantity squared did not significantly explain the variation in short-run average fabrication cost per head. Fewer respondents to the fabrication questionnaire as compared to slaughter may explain the low R^2 values and insignificant t-values.

Logarithmic Functional Form

The quantities associated with each combination of binary variables (as presented in Chapter III, Table 2) were transformed to natural logarithms and a logarithmic model estimated.

Table 11. Long-Run Average Fabrication Cost Estimates From a Quadratic Annual Quantity Model

Independent Variable	$/Head	t-values
Intercept	61.34***[a]	16.03
Quantity of steers and heifers processed per year (X_{81})	-2.9×10^{-5}***	-2.85
Quantity of steers and heifers processed per year squared (X_{82})	$+1.1 \times 1^{11}$*	1.83
R^2 = .183		
n = 146		

[a]Asterisks represent significance levels; ***.01, *.1.

Table 12. Short-Run Average Fabrication Cost Estimates From a Quadratic Annual Quantity Model

Independent Variable	Plant Size: 205 Hd/Hr $/head	205 Hd/Hr t-value	265 Hd/Hr $/head	265 Hd/Hr t-value	325 Hd/Hr $/head	325 Hd/Hr t-value
Intercept	67.08***[a]	5.09	64.29***	5.24	64.16***	5.80
Quantity of steers and heifers fabricated per year (X_{81})	$-5.1x10^{-5}$	-1.08	$-3.8x10^{-5}$	-1.11	$-3.5x10^{-5}$	-1.40
Quantity of steers and heifers fabricated per year squared (X_{82})	$+2.8x10^{11}$	.75	$1.7x10^{11}$	.80	$1.4x10^{11}$	1.08
	R^2 = .146		R^2 = .137		R^2 = .149	
	n = 48		n = 48		n = 48	

[a]Asterisks represent significance levels; ***.01.

Slaughter

Results of the logarithmic long-run average cost slaughter model are presented in Table 13. The estimated parameter on the quantity variable was significant. The R^2 value was between the range of R^2 values from the LBV and quadratic annual quantity models. A logarithmic function assumes average cost per head decreases infinitely and data collected decline over the range considered. However, infinitely decreasing average slaughter cost may be unrealistic due to diseconomies of scale, e.g., the efficiency of management declines and long-run average cost increases after some point (Gould and Ferguson, 1980).

Table 14 presents estimates for the logarithmic form of the short-run average cost slaughter models for 25, 85, and 145 head per hour plant sizes. Parameter estimates are significant although R^2 values are lower than values for the LBV and quadratic models.

Short-run average slaughter cost estimates for the logarithmic models for 205, 265, and 325 head per hour are presented in Table 15. Again, all parameter estimates are significant, but R^2 values are lower than values for the LBV and quadratic models. As discussed previously, the logarithmic model decreases infinitely. However, average cost per head tends to be relatively constant at large plant sizes.

Fabrication

Logarithmic estimates of long-run average fabrication costs are presented in Table 16. Parameter estimates are significant although R^2 value is lower than the R^2 value for the linear and quadratic models.

Table 13. Long-Run Average Slaughter Cost Estimates From a Logarithmic Annual Quantity Model

Independent Variable	$/Head	t-values
Intercept	580.56***[a]	54.63
Quantity of steers and heifers processed per year (X_{81})	-.239***	-26.47
R^2 = .712		
n = 285		

[a]Asterisks represent significance levels; ***.01.

Table 14. Short-Run Average Slaughter Cost Estimates From a Logarithmic Annual Quantity Model for Plant Sizes 25 Hd/Hr., 85 Hd/Hr., and 145 Hd/Hr.

	Plant Size					
	25 Hd/Hr		85 Hd/Hr		145 Hd/Hr	
Independent Variable	$/head	t-value	$/head	t-value	$/head	t-value
Intercept	618.93***[a]	5.14	1742.37***	5.65	1237.94***	4.45
Quantity of steers and heifers slaughtered per year (X_{81})	-.249**	-2.19	-.327***	-3.03	-.295**	-2.35
	R^2 = .134 n = 32		R^2 = .223 n = 33		R^2 = .165 n = 29	

[a]Asterisks represent significance levels; ***.01, **.05.

Table 15. Short-Run Average Slaughter Cost Estimates From a Logarithmic Annual Quantity Model for Plant Sizes 205 Hd/Hr., 265 Hd/Hr., and 325 Hd/Hr.

	Plant Size					
	205 Hd/Hr		265 Hd/Hr		325 Hd/Hr	
Independent Variable	$/head	t-value	$/head	t-value	$/head	t-value
Intercept	1278.32***[a]	16.17	1659.05***	15.63	1768.70***	13.01
Quantity of steers and heifers slaughtered per year (X_{81})	-.299***	-8.84	-.317***	-8.93	-.323***	-7.62
	R^2 = .562		R^2 = .567		R^2 = .487	
	n = 62		n = 62		n = 62	

[a]Asterisks represent significance levels; ***.01.

Table 16. Long-Run Average Fabrication Cost Estimates From a Logarithmic Annual Quantity Model

Independent Variable	$/Head	t-values
Intercept	452.55***[a]	14.91
Quantity of steers and heifers processed per year (X_{81})	-.169***	-5.51
R^2 = .173		
n = 146		

[a]Asterisks represent significance levels; ***.01.

Table 17 presents short-run average logarithmic fabrication cost models. Parameter estimates are significant but again, R^2 values are lower than R^2 values for the LBV and quadratic estimated models.

Best Explanatory Model

The primary objective of this study was to estimate a model explaining the variation in average cost per head for slaughter and fabrication plants. The LBV model explained more of the variation in long-run and short-run average costs per head for slaughter and fabrication plants. The binary variables represent plant sizes as well as plant operating conditions which management can control. Therefore, the LBV model incorporates management's ability to influence average cost per head. Thus, the existence of economies of size and scale in slaughter and fabrication plants are suggested by the LBV model.

Table 17. Short-Run Average Fabrication Cost Estimates From a Logarithmic Annual Quantity Model

	Plant Size					
	205 Hd/Hr		265 Hd/Hr		325 Hd/Hr	
Independent Variable	$/head	t-value	$/head	t-value	$/head	t-value
Intercept	583.47***[a]	7.19	485.75***	7.00	437.47***	7.16
Quantity of steers and heifers fabricated per year (X_{81})	-.189***	-2.79	-.175**	-2.64	-.167***	-2.66
	R^2 = .143		R^2 = .129		R^2 = .131	
	n = 48		n = 48		n = 48	

[a]Asterisks represent significance levels, ***.01.

CHAPTER V

IMPLICATIONS OF RESULTS AND CONCLUSIONS

Costs Compared From Different Functional Forms

Total and Marginal Costs

Regression, using binary independent variables, results in point estimates for the dependent variable. Line segments connection point estimates approximates the long-run average slaughter cost curve and fabrication cost curve. The minimum point on the long-run average slaughter and fabrication cost curves must be estimated in order to determine a minimum efficient plant size.

The minimum point of a curve is determined from the first derivative of the equation which represents the curve. The equation representing the curve must be second order or higher to set the derivative equal to zero and solve for the unknown variable. A derivative of a straight line, with respect to a particular independent variable, is the slope coefficient associated with the independent variable. A LBV (linear binary variable) model has a slope coefficient associated with each binary variable. However, the derivative of a LBV model cannot be used to determine the minimum point on the long-run average cost curve it approximates. Therefore, the long-run average LVB slaughter and fabrication cost models presented in Tables 3 and 6, respectively, cannot be used to determine their respective minimum efficient plant sizes.

Point estimates for each plant size operating one, 8-hour shift per day and 5 days per week (plant operating conditions defined as 100 percent capacity in Chapter III) were used to estimate a quadratic function. Average cost per head was the dependent variable. Quantity processed per year (associated with each plant size operating one, 8-hour shift, 5 days per week) and annual quantity squared were the independent variables. A quadratic function was also estimated from point estimates of average cost per head for each plant size operating two, 8-hour shifts per day and 5 days per week.

As reviewed in Chapter II, long-run average cost is long-run total cost divided by quantity. Therefore, long-run total cost is long-run average cost multiplied by quantity. Long-run marginal cost is the first derivative of long-run total cost.

Slaughter

Estimated long-run average, total, and marginal slaughter cost equations are presented in Table 18. Quadratic equations estimated from the LBV model do not include the effects of hours worked per shift, days worked per week, and capacity utilized on average cost per head. Whereas, quadratic annual slaughter and logarithmic annual slaughter equations include all effects of plant sizes and operating conditions. For example, the quadratic equation estimated from the LBV model representing one, 8-hour shift and 5 days per week only includes the effects from plant size on average cost per head. Whereas, the quadratic equation estimated from the LBV model representing two, 8-hour shifts and 5 days per week includes only effects from plant size and shifts worked per day.

Table 18. Long-Run Average, Total and Marginal Slaughter Cost Equations Using Quadratic Estimated From Linear Binary Variables, Quadratic Annual Quantity, and Logarithmic Annual Quantity Functional Forms

Funcational Form	Cost Equation		
	Average	Total	Marginal
Quadratic[a]	$43.11-6.06x10^{-5}Q$[e]$+4.49x10^{-11}Q^2$ (38.34)[f] (-8.37) (4.64) R^2 = .989	$43.11Q-6.06x10^{-5}Q^2+4.49x10^{-11}Q^3$	$43.11-1.21x10^{-4}Q+1.35x10^{-10}Q^2$
Quadratic[b]	$37.28-2.60x10^{-5}Q+9.43x10^{-12}Q^2$ (18.83) (-3.66) (1.90) R^2 = .952	$37.29Q-2.60x10^{-5}Q^2+9.43x10^{-12}Q^3$	$37.29-5.21x10^{-5}Q+2.83x10^{-11}Q^2$
Quadratic[c]	$42.02-4.3x10^{-5}Q+2.0x10^{-11}Q^2$ (61.76) (-17.79) (10.76) R^2 = .688	$42.02Q-4.3x10^{-5}Q^2+2.0x10^{-11}Q^3$	$42.02-8.5x10^{-5}Q+6.1x10^{-11}Q^2$
Logarithmic[d]	$580.56Q^{-.239}$ (54.63) (-26.47) R^2 = .712	$580.56Q^{.761}$	$441.81Q^{-.239}$

Table 18. (Continued)

[a]Quadratic model estimated from point estimates from the LBV model representing one 8-hour shift, 5 days per week, at 100 percent capacity.

[b]Quadratic model estimated from point estimates from the LBV model representing two 8-hour shifts, 5 days per week, at 100 percent capacity.

[c]Quadratic model estimated from quantity of steers and heifers slaughtered per year (as presented in Chapter III, Table 2).

[d]Logarithmic model estimated from quantity of steers and heifers slaughtered per year (as presented in Chapter III, Table 2).

[e]Quantity of steers and heifers slaughtered per year.

[f]Numbers in parenthesis are t-values.

Figure 7 illustrates long-run average slaughter cost equations from Table 18. Equations were estimated over the quantity range 25 head per hour to 325 head per hour. Then the curves were extrapolated to illustrate the shapes. The quadratic equation estimated from the LBV model (two 8-hour shifts, 5 days per week plant operating conditions) was not included in Figure 7 because of scaling difficulties.

The average cost curve from the quadratic equation estimated from the LBV model (single shift model) reaches a minimum at 675,200 head slaughtered per year or 325 head per hour and the quadratic estimated from the LBV model (double shift model) reaches a minimum at 1,380,250 head slaughtered per year or 332 head per hour. The average cost curve from the quadratic estimated from annual quantity reaches a minimum at 1,052,980 head slaughtered per year (Table 20). Whereas, the curve from the logarithmic equation estimated from quantity declines infinitely (characteristic of a logarithmic function discussed in Chapter IV).

Fabrication

Estimated long-run average, total, and marginal fabrication cost equations are presented in Table 19. The LBV model presented in Chapter IV, Table 6 considered just three plant sizes due to data limitations or smaller sized plants. To estimate a quadratic function from the LBV model requires more than three points. Thus, estimating a quadratic equation from the LBV model was not possible.

Figure 8 compares the long-run average cost curves from the estimated quadratic and logarithmic annual quantity equations in Table 19. Equations were estimated over the quantity range corresponding to

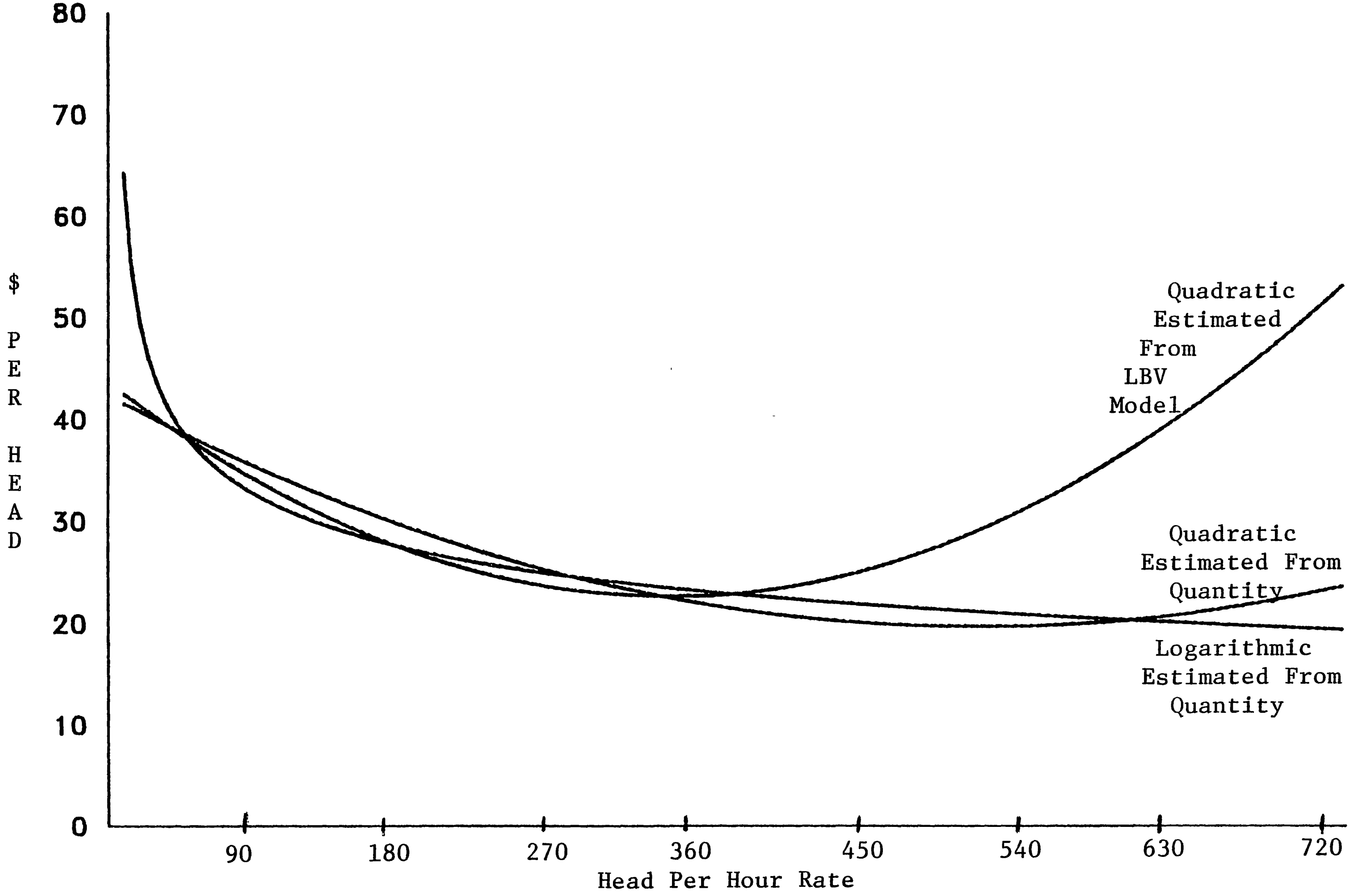

Figure 7. Comparison of Estimated Long Run Average Slaughter Cost Curves Using Different Functional Forms

Table 19. Long Run Average, Total and Marginal Fabrication Cost Equations Using Quadratic and Logarithmic Annual Quantity Functional Forms

Functional Form	Cost Equation: Average	Cost Equation: Total	Cost Equation: Marginal
Quadratic[a]	$61.34-2.9x10^{-5}Q^{c}+1.1x10^{-11}Q^{2}$ (16.03)[d] (-2.85) (1.83) R^2 = .183	$61.34Q-2.9x10^{-5}Q^{2}+1.1x10^{-11}Q^{3}$	$61.34-5.9x10^{-5}Q3.4x10^{-11}Q^{2}$
Logarithmic[b]	$452.55Q^{-.169}$ (14.91) (-5.51) R^2 = .173	$452.55Q^{.831}$	$376.07Q^{.-.169}$

[a]Quadratic model estimated from quantity of steers and heifers slaughtered per year (as presented in Chapter III, Table 2).

[b]Logarithmic model estimated from quantity of steers and heifers slaughtered per year (as presented in Chapter III, Table 2).

[c]Quantity of steers and heifers fabricated per year.

[d]Numbers in parenthesis are t-values.

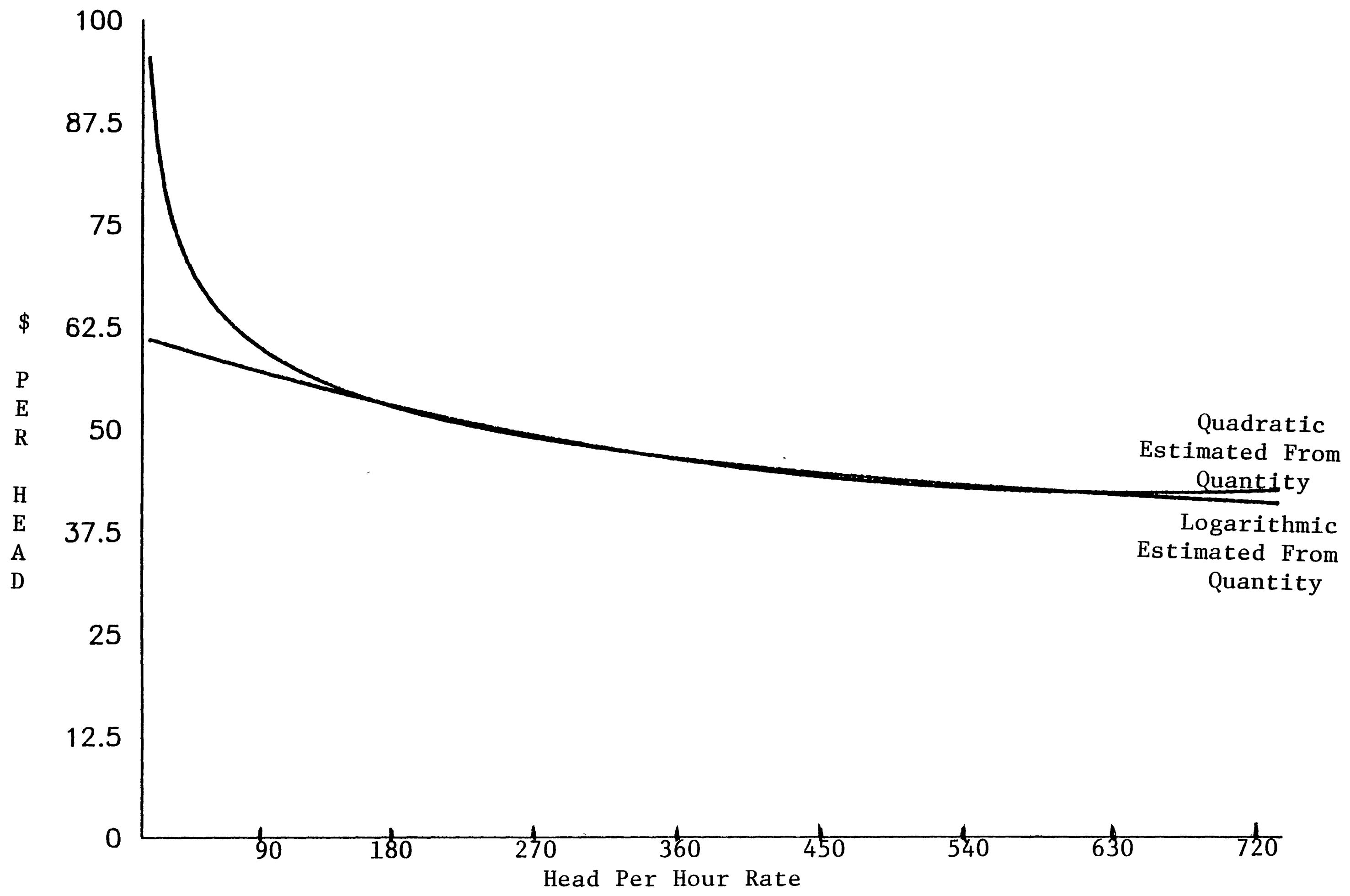

Figure 8. Comparison of Estimated Long-Run Average Fabrication Cost Curves Using Different Functional Forms

205 head per hour to 325 head per hour. Then the curves were extrapolated to illustrate the shapes. The long-run average cost quadratic equations estimated from quantity reaches a minimum at 1,285,440 head fabricated per year. The average cost logarithmic curve declines infinitely.

Minimum Efficient Plant Size

Minimum efficient plant size is a plant sufficiently large enough to capture the economies of scale in the steer and heifer processing industry. A smaller plant size will have a higher average cost per head. In this section, minimum efficient plant sizes derived from the quadratic equation estimated from the LBV model, quadratic annual quantity equation, and logarithmic annual quantity equation are compared.

Slaughter

Table 20 presents minimum long-run average slaughter costs and minimum efficient plant sizes determined from the quadratic equations estimated from the LBV model and the quadratic equation estimated from quantity (Table 18). The first derivative of the three quadratic equations presented in Table 18 was set equal to zero to determine the minimum efficient output.

The quadratic equations estimated from the LBV model have specifically defined plant operating conditions associated with them. Therefore, a minimum efficient plant size (i.e., head per hour rate) can be determined. The quadratic equation estimated from the LBV model based on one, 8-hour shift per day and 5 days per week plant operating condition reaches a minimum efficient plant size at 325 head per hour

Table 20. Comparison of Minimum Long Run Average Slaughter Costs and Minimum Efficient Plant Sizes

Functional Forms	LRAC[a]	Annual Head Slaughtered
Quadratic[b]	22.64	675,200
Quadratic[c]	19.32	1,380,250
Quadratic[d]	19.66	1,051,980

[a]Long run average cost in dollars per head units.

[b]Quadratic equation estimated from point estimates from the LBV model based on one 8-hour shift per day, five days per week at 100 percent capacity.

[c]Quadratic equation estimated from point estimates from the LBV model based on two 8-hour shifts per day, 5 days per week at 100 percent capacity.

[d]Quadratic equation estimated from quantity of steers and heifers slaughtered per year (as presented in Chapter III, Table 2).

(conversion from head per hour to annual head slaughtered is discussed in Chapter III). Whereas, the quadratic equation based on two, 8-hour shifts per day and 5 days per week plant operating conditions reaches a minimum efficient plant size at 332 head per hour.

Plant operating conditions cannot be determined for the quadratic equation estimated from annual quantity. Thus, a minimum efficient plant size cannot be determined. Therefore, an annual head slaughtered can only be associated with the minimum long-run average cost determined from the quadratic equation estimated from quantity. This annual slaughter rate could be reched by operating 8 to 10 hours per shift, 5 to 6 days per week, or 1 to 2 shifts per day.

The annual head slaughtered associated wtih the quadratic equation estimated from the LBV model based on one, 8-hour shift per day and 5 days per week has the lowest annual slaughter rate. This is due to only considering estimated average costs associated with one 8-hour shift per day and 5 days per week plant operating conditions from the LBV model. For the same reason, the quadratic equation estimated from the LBV model based on two, 8-hour shifts per day and 5 days per week has the highest annual slaughter rate. Annual head slaughtered estimated from the quadratic equation estimated from quantity falls between the annual slaughter rates of two quadratic equations estimated from the LBV model. The annual slaughter quadratic model is based on all combinations of selected plant operating conditions.

The curve estimated from the logarithmic average cost per head equation (Table 18) does not reach a minimum. However, average costs per head from the logarithmic equation can be compared to the minimum average costs presented in Table 20. Average costs per head associated with 675,200, 1,380,250, and 1,051,980 head slaughtered per year are $23.48, $19.79, and $21.11, respectively.

Fabrication

The quadratic annual quantity equation presented in Table 19 reaches a minimum at 1,285,088 head fabricated annually with a long-run average cost per head of $42.49. The logarithmic equation estimates an average cost per head of $42.00 at 1,285,088 annual head fabricated. Plant operating conditions associated with the annual fabrication rate cannot be determined for the quadratic or logarithmic equations estimated from quantity. Therefore, the minimum efficient plant size cannot be determined from the annual fabrication volume.

Alternative Market Structures Compared

Scherer (1980) suggests cost structure is an important determinant of industry market structure. In this section, alternative market structures are compared for the steer and heifer industry, e.g., equilibrium, perfect competition, and the current structure as of 1982. Inferences about conduct and performance can be made from market structure (Sherer's model in Chapter II, Figure 1).

Slaughter

Table 21 compares long-run average slaughter cost among alternative market structure estimates. Equilibrium market structure scenarios are estimated from long-run average costs and annual head slaughtered as presented in Table 20. Scenario I is based on the quadratic equation estimated from the LBV model with one, 8-hour shift per day and 5 days

Table 21. Comparison of Long Run Average Slaughter Cost Among Alternative Market Structure Estimates

Market Structure	LRAC[a]	Average Plant Size	No. of Plants in the Industry[b]
	$/hd		
Equilibrium Structure			
Scenario I	22.64	675,200	38
Scenario II	19.32	1,380,250	18
Scenario III	19.66	1,051,980	24
Perfect Competition			
Scenario I	40.08	52,000	490
Scenario II	33.80	176,800	144
Scenario III	28.92	301,600	85
Current Industry Structure[c]	29.10	407,175	513

[a]Long run average cost.

[b]Determined by dividing total steer and heifer slaughter output (25,485,800) by average plant size.

[c]

Size Category	LRAC	No. of Plants	Volume	Weight
0- 49,999	41.62	422	2,446,700	.096
50,000- 99,999	38.82	31	2,292,800	.090
100,000-249,999	33.88	28	4,497,000	.176
250,000-499,999	26.70	20	7,118,700	.279
≤ 500,000	22.92	12	9,130,600	.358

per week plant operating conditions (Table 18). Baumol's (1967) market structure model discussed in Chapter II and illustrated in Figure 2 is used to estimate the number of plants in the steer and heifer slaughter industry under alternative market structures. The minimum efficient annual slaughter rate is estimated from the minimum point on the quadratic curve estimated from the LBV model with one, 8-hour shift per day and 5 days per week plant operating conditions. Thus, the minimum efficient plant would be 325 head per hour at an average cost of $22.64 per head under Scenario I assumptions. Total steer and heifer slaughter reported to Packers and Stockyards Administration (1983) was 25,485,800 head in 1982. Thus, using Baumol's (1967) market structure model there would be 38 plants in the steer and heifer industry assuming Scenario I under equilibrium conditions.

Scenario II under equilibrium market structure is based on the quadratic equation estimated from the LBV model with two, 8-hour shifts per day and 5 days per week plant operating conditions (Table 18). Minimum efficient plant size would be 332 head per hour with a long-run average cost of $19.32 per head. There would be 18 plants in the slaughter industry under Scenario II.

Equilibrium Scenario III is based on the quadratic equation estimated from annual quantity (Table 18). As discussed earlier, a minimum efficient plant size cannot be determined only a minimum efficient annual slaughter rate can be estimated. Based on Scenario III estimates, 24 plants would be required in the slaughter industry.

Any one of the equilibrium scenarios implies the steer and heifer slaughter industry will be comprised of a few large plants. With multiplant firms becoming more important, it is possible for total industry output to be produced by a smaller number of firms than estimated under equilibrium market structure scenarios.

Plant size under perfect competition is defined as a plant small enough so as not to affect market price or volume offered in the market place (Gould and Ferguson, 1980). Thus, there is not a unique number of plants that defines a perfectly competitive market. Therefore, three scenarios were defined under perfect competition in Table 21.

Scenario I assumes all plants are equal to the smallest plant size considered in this study, 52,000 annual head slaughtered (or 25 head per hour). When the survey questionnaire was pretested, industry participants agreed the majority of plants in the steer and heifer industry were built with the intention of operating one, 8-hour shift per day and 5 days per week. Also, the minimum efficient output (i.e., 647,200 head per year) estimated for these plant operating conditions (i.e., one, 8-hour shift per day and 5 days per week) was in the middle of existing plant sizes reported by Packers and Stockyards Administration, (1983). Thus, the quadratic equation estimated from the LBV model based on one, 8-hour shift per day and 5 days per week was used to estimate the long-run average costs under the perfectly competitive market structure. Scenario I estimates long-run average cost to be $40.08 per head with 490 plants in the industry.

Scenario II under perfect competition assumes all plants are equal to the second smallest plant size in this study (defined as 176,800 annual slaughter rate or 85 head per hour). Average cost is estimated at $33.80 per head with 144 plants in the industry.

Scenario III assumes all plants are equal to the third smallest plant size (301,600 annual head slaughtered or 145 head per hour) used in this study. Number of plants estimated in the industry is 85 with each plant having a long-run average cost of $28.92 per head.

Packers and Stockyards Administration reports number of plants and volume by size category (Table 21). Current industry average plant size is the summation of average plant size by category times a respective weight which is the proportion each size category's volume is of the total volume. Long-run average cost for each size category was estimated from the quadratic equation estimated from the LBV model with one 8-hour shift per day and 5 days per week plant operating conditions. The midpoint of each size category was used to estimate average cost per head, except 750,000 head per year was arbitrarily used for the size category greater than or equal to 500,000 head per year. Industry average cost is the summation of weighted average cost per head.

Estimated plant size for the current industry structure is larger than plant size in Scenario III under perfect competition. However, average cost per head is larger under current industry structure than in Scenario III under perfect competition. Current industry plant size and average cost per head considers plants to be different sizes with differing average costs per head. Whereas, perfect competition Scenario III assumes all plants in the industry are the same size with the same average cost per head.

If the trend discussed in Chapter I and presented in Table 1 continues (i.e., plants becoming fewer and larger in the steer and heifer slaughter industry), then current industry average plant size can be expected to increase and approach one of the equilibrium market structure scenarios. As plants become larger, smaller plants cease operating (Chapter I, Table 1). This suggests current industry average cost per head would decrease.

Fabrication

Table 22 compares alternative market structure estimates for steer and heifer fabrication. Total fabrication output in 1982 included only plants that slaughter and fabricate (Packers and Stockyards Administration, 1985). Therefore, total 1982 fabrication output is understated.

The equilibrium market structure is based on the annual fabrication quadratic equation (Table 19). The logarithmic equation does not reach a minimum, therefore, a minimum efficient plant output cannot be determined. A minimum efficient plant size for the equilibrium market structure cannot be calculated because plant operating conditions cannot be determined from the quadratic equation estimated from annual quantity.

Perfect competition Scenarios I, II, and III average plant sizes were developed in the same manner as average plant sizes in slaughter. The quadratic equation estimated from annual quantity was used to estimate the long-run average cost for each scenario, by the same procedures discussed in the slaughter section.

Average fabrication cost per head for the current industry and average plant size were determined by the same procedure used for slaughter. Number of plants and volume by size category were provided by Packers and Stockyards Administration (1985).

Number of plants in the current industry structure category are comparable to the number of plants for perfect competition Scenario II. Thus, average cost per head differs for current industry structure as compared to perfect competition Scenario II.

Table 22. Comparison of Long Run Average Fabrication Cost Among Alternative Market Structure Estimates

Market Structure	LRAC[a]	Average Plant Size	No. of Plants in the Industry[b]
	$/hd		
Equilibrium Structure	42.49	1,285,088	12
Perfect Competition			
Scenario I	59.86	52,000	285
Scenario II	56.56	176,800	84
Scenario III	52.69	301,600	49
Current Industry Structure[c]	48.79	605,661	88

[a]Long run average cost.

[b]Determined by dividing total steer and heifer fabrication output (14,811,000) by average plant size.

[c]

Size Category	LRAC	No. of Plants	Volume	Weight
0- 49,999	60.62	57	707,000	.048
50-000- 99,999	59.23	3	204,000	.014
100,000-249,999	56.60	9	1,735,000	.117
250,000-499,999	52.01	6	1,999,000	.135
$\leq$ 500,000	45.78	13	10,166,000	.686

If the trend toward fewer and larger plants continues then current industry average plant size can be expected to increase and approach one of the equilibrium market structure scenarios. This suggests current industry average cost per head would decrease.

Conduct

The following discussion focuses on pricing behavior which is a component of conduct (Chapter II, Figure 1). Slaughter plants are used in this discussion, however, an identical discussion could be developed for fabrication plants.

If plants pay the same price for cattle and sell carcasses at the same price (as discussed in Chapter II), then plants with lower operating costs (i.e., average cost per head) will have higher profits. Results from this study indicate larger plants (325 head per hour) have lower average costs per head compared with smaller plants.

If plants pay the same price for cattle, then plants with lower operating costs will have a larger profit margin (difference between revenues and costs). Thus, low-cost plants can sell carcasses for a lower price than competitors operating with higher average costs. Low-cost plants can then bid volume away from high-cost competitors, thus expanding their plant output.

If plants receive the same price for carcasses then lower-cost plants can pay more for cattle. Bidding cattle away from higher-cost competitors will expand plant output and low-cost plants will control a larger portion of total fed cattle. Table 3 in Chapter IV suggests that if the cost of transporting fed cattle to the slaughter plant becomes too high, then a larger plant (325 head per hour) has the option to operate at 90 percent capacity and still remain a lower-cost plant as compared to a smaller plant (205 head per hour).

Performance

Production efficiency is a measure of performance (Scherer, 1980). Average cost per head can be used to measure production efficiency. Results from this study indicate as plants move from a small size (25 head per hour) to a larger size (325 head per hour), average cost per head decreases. This suggests larger plants are more efficient than smaller plants. If production efficiency is an important goal of society, resutls from this study suggest the steer and heifer processing industry should continue restructuring towards fewer, larger plants.

Conclusions

Results presented in Chapter IV suggest economies of size and scale exist in the steer and heifer processing industry. For larger plant sizes, increasing hours worked per day, days worked per week, and shifts worked per day generally reduced average cost per head. Operating at less than 100 percent capacity increased average cost per head. Although some of the parameter estimates were not significant by statistical measures, this does not necessarily indicate small reductions in average cost per head are not significant to plant managers.

The six parameter estimates associated with the plant size variable were significantly different from each other. Thus, each average cost per head by plant size (representing one, 8-hour shift per day and 5 days per week operating conditions) was significantly different from other average costs per head by plant size. The minimum efficient output for slaughter plants ranged from 2 to 5 percent of total output depending on which equilibrium structure scenario is considered (Table 21). Fabrication minimum efficient output was 8.7 percent of total output (Table 22). This suggests economies of scale are more important in fabrication than in slaughter.

Baumol (1982) suggests barriers to entry are associated with economies of scale. A minimum efficient plant size creates a barrier to entry due to cost advantages over smaller plants. Economies of scale prevent entry into a market, if the minimum efficient plant size is a large enough fraction of total output such that an additional minimum efficient plant would significantly reduce market price. Although this study did not consider this, it is possible that economies of scale are a barrier to entry in the steer and heifer processing industry.

Average cost per head and average plant size estimates suggest current industry structure is somewhere between estimates for equilibrium and perfect competition market structures for slaughter and fabrication. If the trend toward fewer and larger plants continues, then average cost per head will decrease. Plants with lower average costs will have an advantage in gaining greater market shares in the fed cattle, carcass, and fabrication markets compared with higher cost plants.

CHAPTER VI

SUMMARY AND FURTHER RESEARCH NEEDS

Summary

Problem and Objectives Restated

Firms slaughtering 100,000 head or less annually have declined in percent of slaughter by all firms reporting steer and heifer slaughter between 1977 and 1982 (Chapter I, Table 1). In 1982, firms slaughtering 500,000 head or more annually represented 2.1 percent of all slaughter firms but accounted for 65.3 percent of total slaughter.

One possible explanation for firms becoming larger is economies of size and scale. Economies of size assumes plant size is fixed, while plant utilization is variable (i.e., hours worked per shift, days worked per week, shifts worked per day, and capacity utilized). Economies of scale assumes both plant size and operating conditions can vary. Processing costs (slaughter and fabrication), directly influenced by management, are used to explain variation in average costs per head among different plant sizes. If average cost per head declines over a wide range of plant sizes then economies of scale may be important in explaining the restructuring of the steer and heifer processing industry.

Economies of scale studies for the beef processing industry are outdated. Plants are larger than the largest plant considered in previous studies. Plant operating conditions which affect processing costs (i.e., hours worked per shift, days worked per week, shifts worked per day, and capacity utilized) have not been considered in past economies of scale studies.

Specific objectives for this study were: (1) develop long-run and short-run models to estimate average cost per head for steer and heifer processing plants; (2) determine the minimum efficient plant size for slaughter and fabrication plants; (3) determine the equilibrium market structure based on the long-run average cost curves for slaughter and fabrication plants; and (4) determine implications for future structure, conduct, and performance of the steer and heifer processing industry.

Procedures

A survey questionnaire was sent to plants that slaughter and/or fabricate steers and heifers. The questionnaire presented a base situation for which participants were asked to estimate average cost per head under different plant sizes. Next, the following plant operating conditions were varied one at a tme: (1) hours worked per shift; (2) days worked per week; (3) shifts worked per day; and (4) capacity utilized. For each plant size, an average cost per head was estimated when plant operating conditions varied.

A linear binary variable (LBV) model was estimated from the average cost per head data collected. Quadratic and logarithmic models based on annual quantity were also estimated. The three models were estimated across plant sizes and within each plant size to provide long- and short-run average cost per head estimates.

Findings

The LBV model explained the most variation in average cost per head of the three models estimated both for slaughter and fabrication. Average costs per head estimated from the LBV model could be attributed to plant size and operating conditions. This was not possible with the annual volume quadratic and logarithmic models, which considered total annual quantity only. Plants processing 145 head per hour or less generally cannot significantly affect average cost per head by changing plant operating conditions. Plants processing 205 head per hour or more can significantly change average cost per head. Thus, significant economies of size exist for plants 205 head per hour or larger. Parameter estimates associated with each plant size were significant, suggesting economies of scale are also important in the steer and heifer processing industry.

Minimum efficient plant size was larger for fabrication than for slaughter. This may suggest economies of scale are more important for fabrication than for slaughter. If the trend towards fewer and larger slaughter and fabrication plants continues, then average cost per head can be expected to decline. Low-cost plants can be expected to pay more for cattle, price carcasses lower than high-cost plants in order to increase their percent of total industry output, or earn higher profits.

Further Research Needs

Bain (1968) suggests there are economies of scale associated with vertical integration and multiplant firms. In 1982 integrated slaughter and fabrication plants existed in the industry, as well as multiplant firms. Average cost variation attributed to integrated plants and multiplant firms needs to be incorporated into the LBV model.

The LBV model estimated did not consider interaction among plant operating conditions. If interaction is significant among plant operating conditions, then some parameter estimates may be overstated while others may be understated in this study. Thus, interaction among plant operating conditions needs to be considered in the LBV model.

Additional survey responses, especially from fabrication plants would have enabled cost estimates to be based on more observations. This may have led to improved results. Several managers (generally from small plant sizes) contacted by telephone indicated they did not know effects of plant size and operating conditions on average cost per head. Had more smaller fabrication firms participated in the survey, a long-run average quadratic equation cost could have been estimated from the LBV model.

Management objectives in industrial organization analysis are important in explaining firm behavior (Scherer, 1980) and may be an important variable in explaining average cost per head in the steer and heifer processing industry. Thus, alternative management objectives to profit maximization need to be further analyzed.

Baumol's model illustrated in Figure 2 (Chapter II) is not supported by empirical evidence. Further research needs to be done on the validity of determining equilibrium structure from the long-run average cost curve.

In Chapter II, production costs of the steer and heifer processing industry were subdivided into three component parts (i.e., procurement, processing, and selling costs). This study only considered processing costs. Models need to be developed for procurement and selling costs in order to study the optimum number and location of steer and heifer processing plants in the industry.

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APPENDIX A

STEER AND HEIFER SLAUGHTER

SURVEY QUESTIONNAIRE

SLAUGHTER SURVEY QUESTIONNAIRE

Base situation: Each plant slaughters fed steers and heifers and was built in 1980. Each plant has appropriate cooler space for the number of cattle specified per hour and per day in Columns A-C. Each plant operates one, 8-hour shift, 5 days/week and has a guaranteed 40-hour/week agreement with labor. Base pay for plant labor in each plant is $7.50/hour with a 35 percent fringe benefit package.

The following questions ask for YOUR BEST ESTIMATE of costs per head to slaughter cattle in each plant for the base situation and alternative situations. Costs/head should include costs from the time cattle arrive at the plant to the time carcasses leave the plant or are transferred to the processing department. Costs/head should include costs for edible and inedible rendering, hide processing, overhead costs such as corporate management land, buildings, and equipment costs, interest, and other operating costs.

	Plant Sizes A	B	C
Slaughter rate-head/hour	25	85	145
Slaughter rate-head/day (8-hour shfit)	200	680	1160

Costs/Head ($/hd)

	A	B	C
1. What is YOUR BEST ESTIMATE of each plant's slaughter costs/head under the base situation?	____	____	____

For questions 2-4, assume ample supplies of cattle are available and plants described in the base situation expand their slaughter volume (either by increasing hours/day, days/week, or shifts/day).

2. Assume each plant slaughters 5 days/week but more hours/day.

	A	B	C
a. Slaughter rate/head/day (9-hour shift)	225	765	1305
What is each plant's slaughter costs/head?	____	____	____
b. Slaughter rate-head/day (10-hour shift)	250	850	1450
What is each plant's slaughter costs/head?	____	____	____

3. Assume each plant slaughters 8-hour days (as in question 1) but slaughters 6 days/week.

	A	B	C
What is each plant's slaughter costs/head?	____	____	____

4. Assume each plant slaughters 2, 8-hour shifts/day, 5 days/week.

	A	B	C
Slaughter rate-head/day	400	1360	2320
What is each plant's slaughter costs/head?	____	____	____

For question 5, assume the plants are forced to to cut back the number of head slaughtered due to external forces.

5. Assume each plant slaughters 40 hours/week but at a slower chain speed.

	A	B	C
a. Slaughter rate-head/hour (90% of capacity)	22	76	130
Slaughter rate-head/day	180	612	1044
What is each plant's slaughter costs/head?	____	____	____
b. Slaughter rate-head/hour (80% of capacity)	20	68	116
Slaughter rate-head/day	160	544	928
What is each plant's slaughter costs/head?	____	____	____

	Number of Wage Employees A	B	C
6. Under the base situation (question 1) how many wage employees are required for each plant size.	____	____	____

	Plant Sizes		
	A	B	C
Slaughter rate-head/hour	205	265	325
Slaughter rate-head/day (8-hour shift)	1640	2120	2600

Costs/Head ($/hd)

1. What is YOUR BEST ESTIMATE of each plant's slaughter costs/head under the base situation? ____ ____ ____

For questions 2-4, assume ample supplies of cattle are available and plants described in the base situation expand their slaughter volume (either by increasing hours/day, days/week, or shifts/day).

2. Assume each plant slaughters 5 days/week but more hours /day.

   a. Slaughter rate-head/day (9-hour shift) 1845 2385 2925
      What is each plant's slaughter costs/head? ____ ____ ____

   b. Slaughter rate-head/day (10-hour shift) 2050 2650 3250
      What is each plant's slaughter costs/head? ____ ____ ____

3. Assume each plant slaughters 8-hour days (as in question 1) but slaughters 6 days/week.

   What is each plant's slaughter costs/head? ____ ____ ____

4. Assume each plant slaughters 2, 8-hour shifts/ day, 5 days/week.

   Slaughter rate-head/day 3280 4240 5200
   What is each plant's slaughter costs/head? ____ ____ ____

For question 5, assume the plants are forced to cut back the number of head slaughtered due to external forces.

5. Assume each plant slaughters 40 hours/week but at a slower chain speed.

   a. Slaughter rate-head/hour (90% of capacity) 184 238 292
      Slaughter rate-head/day 1476 1908 2340
      What is each plant's slaughter costs/head? ____ ____ ____

   b. Slaughter rate-head/hour (80% of capacity) 164 212 260
      Slaughter rate-head/day 1312 1696 2080
      What is each plant's slaughter costs/head? ____ ____ ____

6. Under the base situation (question 1) how many wage employees are requried for each plant size?

   Number of Wage Employees
   ____ ____ ____

APPENDIX B

STEER AND HEIFER FABRICATION

SURVEY QUESTIONNAIRE

FABRICATION SURVEY QUESTIONNAIRE

Base situation: Each plant fabricates beef carcasses and was built in 1980. Each plant has appropriate cooler space for the number of carcasses specified per hour and per day in Columns A-C. Each plant operates one, 8-hour shift, 5 days/week and has a guaranteed 40-hour/week agreement with labor. Base pay for plant labor in each plant is $7.00/hour with a 35 percent fringe benefit package.

The following questions ask for YOUR BEST ESTIMATE of costs per head to process cattle in each plant for the base situation and alternative situations. Costs/head should include costs from the time carcasses arrive at the plant or are transferred from the slaughter department to the time boxed products leave the plant. Costs/head should include overhead costs such as corporate management, land, buildings, and equipment costs, interest and other operating costs.

	Plant Sizes		
	A	B	C
Processing rate-head/hour	205	265	325
Processing rate-head/day (8-hour shift)	1640	2120	2600

Costs/Head ($/hd)

1. What is YOUR BEST ESTIMATE of each plant's processing costs/head under the base situation? ____ ____ ____

For questions 2-4, assume ample supplies of carcasses are available and plants described in the base situation expand their processing volume (either by increasing hours/day, days/week, or shifts/day).

2. Assume each plant processing 5 days/week but more hours/day.

   a. Processing rate-head/day (9-hour shift) 1845 2385 2925
   What is each plant's processing costs/head? ____ ____ ____

   b. Processing rate-head/day (10-hour shift) 2050 2650 3250
   What is each plant's processing costs/head? ____ ____ ____

3. Assume each plant processing 8-hour days (as in question 1) but processes 6 days/week.

   What is each plant's processing costs/head? ____ ____ ____

4. Assume each plant processes 2, 8-hour shifts/day, 5 days/week.

   Processing rate-head/day 3280 4240 5200
   What is each plant's processing costs/head? ____ ____ ____

For question 5, assume plants are forced to cut back the number of head processed due to external forces.

5. Assume each plant processes 40 hours/week but at a slower rate.

   a. Processing rate-head/hour (90% of capacity) 184 238 292
   Processing rate-head/day 1476 1908 2340
   What is each plant's processing costs/head? ____ ____ ____

   b. Processing rate-head/hour (80% of capacity) 164 212 260
   Processing rate-head/day 1312 1696 2080
   What is each plant's processing costs/head? ____ ____ ____

6. Under the base situation (question 1) how many wage employees are required for each plant size?

   Number of Wage Employees ____ ____ ____

	Plant Sizes A	B	C
Processing rate-head/hour	25	85	145
Processing rate-head/day (8-hour shift)	200	680	1160

Costs/Head ($/hd)

1. What is YOUR BEST ESTIMATE of each plant's processing costs/head under the base situation? ____ ____ ____

For questions 2-4, assume ample supplies of carcasses are available and plants described in the base situation expand their processing volume (either by increasing hours/day, days/week, or shifts/day).

2. Assume each plant processing 5 days/week but more hours/day.

   a. Processing rate-head/day (9-hour shift) 225 765 1305
      What is each plant's processing costs/head? ____ ____ ____

   b. Processing rate-head/day (10-hour shift) 250 850 1450
      What is each plant's processing costs/head? ____ ____ ____

3. Assume each plant processing 8-hour days (as in question 1) but processes 6 days/week.

   What is each plant's processing costs/head? ____ ____ ____

4. Assume each plant processes 2, 8-hour shifts/ day, 5 days/week.

   Processing rate-head/day 400 1360 2320
   What is each plant's processing costs/head? ____ ____ ____

For question 5, assume plants are forced to cut back the number of head processed due to external forces.

5. Assume each plant processes 40 hours/week but at a slower rate.

   a. Processing rate-head/hour (90% of capacity) 22 76 130
      Processing rate-head/day 180 612 1044
      What is each plant's processing costs/head? ____ ____ ____

   b. Processing rate-head/hour (80% of capacity 20 68 116
      Processing rate-head/day 160 544 928
      What is each plant's processing costs/head? ____ ____ ____

6. Under the base situation (question 1) how many wage employees are required for each plant size?

   Number of Wage Employees ____ ____ ____

VITA

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