ADAPTIVE PLANNING UNDER PRICE UNCERTAINTY
IN SWINE PRODUCTION

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PREFACE

The purpose of this study was to determine whether production and marketing flexibility in response to expected price changes could be used to increase profit for a farrow-to-finish swine enterprise. A simulation model was used to examine six management strategies and five price prediction methods for two swine systems. Accumulated returns over a ten year period were used to evaluate alternative plans.

The author wishes to express a sincere debt of graditude to his major adviser, Dr. Joseph E. Williams for his assistance and constructive criticism throughout the study. Dr. Williams' guidance, reassurance and patience has helped to make my graduate studies both productive and enjoyable. Appreciation is also expressed to the other committee members, Dr. John E. Ikerd, Dr. Charles V. Maxwell, and Dr. Odell L. Walker, for their assistance and suggestions on the final manuscript. Special thanks is extended to Dr. Ikerd for serving as chairman of my committee and for assisting in the development of the research topic.

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The people who have made the greatest sacrifice are my family. I am deeply appreciative of the encouragement and financial support provided by my parents, Forest and Evelyn Plain, and my brother, James. The greatest sacrifices were made by my wife, Cuba. Her love, understanding and encouragement made the most difficult problem seem trivial.

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CHAPTER I

INTRODUCTION

Hog production is a major component of U. S. agriculture. In 1980 over 90 million hogs were raised in the United States on 674 thousand farms. The total value of U. S. hog production was nine billion dollars which made hogs the fifth most important agricultural commodity in the nation during 1980. Only beef cattle, corn, milk, and soybeans contributed more to farm income. Hogs are the ninth ranking agricultural commodity in Oklahoma, contributing about 50 million dollars annually to cash receipts.

Although it is generally considered to be a stable and profitable enterprise, there are many risks and uncertainties involved in pork production. Harsh winters can reduce the average litter size in the corn belt and therefore the nation's winter pig crop. Disease outbreaks such as TGE (transmissable gastro-enteritis) and pseudorabies can devastate a farmer's herd. Unexpected high feed costs can turn a comfortable profit margin into a discomforting loss. But no other risk or uncertainty has as much effect on the income of hog producers as does uncertainty about hog prices.

Hog prices vary widely and often suddenly and unexpectedly. During the 1970s weekly averages of Oklahoma City slaughter hog prices ranged from a low of 15.62 dollars per hundredweight in December, 1970, to a high of 63.16 dollars per hundredweight in October, 1975. Twice during the ten years hog prices varied as much as 26.50 dollars per hundredweight within a 12 month period. The range of hog prices is depicted in Figure 1. Pronounced fluctuation in hog prices leads to wide variation in income for swine producers. High prices and low costs can result in large profits, but when hog prices are low, covering just the variable costs of production may be impossible.

Problem Situation

One of the fundamentals of microeconomic theory is that profit is maximized by producing where marginal cost equals marginal revenue. For an individual hog producer, marginal revenue is equal to the market price. Since hog prices vary widely and are not always positively correlated with costs, it follows that the profit-maximizing level of production also varies.

Wide variation in hog prices results in even wider variation in income for hog producers. Producers often try to take advantage of high prices and insulate themselves from low prices by altering their production level, hoping to have more hogs to sell when prices are high and fewer when prices are low. Many swine producers vary the size of their operation in response to current market prices. Production is expanded when prices are high and contracted when prices are low. Unfortunately, due to production lags, producers often find that production adjustments occur too late to take advantage of the price trends. An alternative some swine producers might choose is to ignore price variation and produce where average total cost is minimized.

Casual observation of the U. S. swine industry tends to indicate that the strategy of expansion and contraction has been common in the

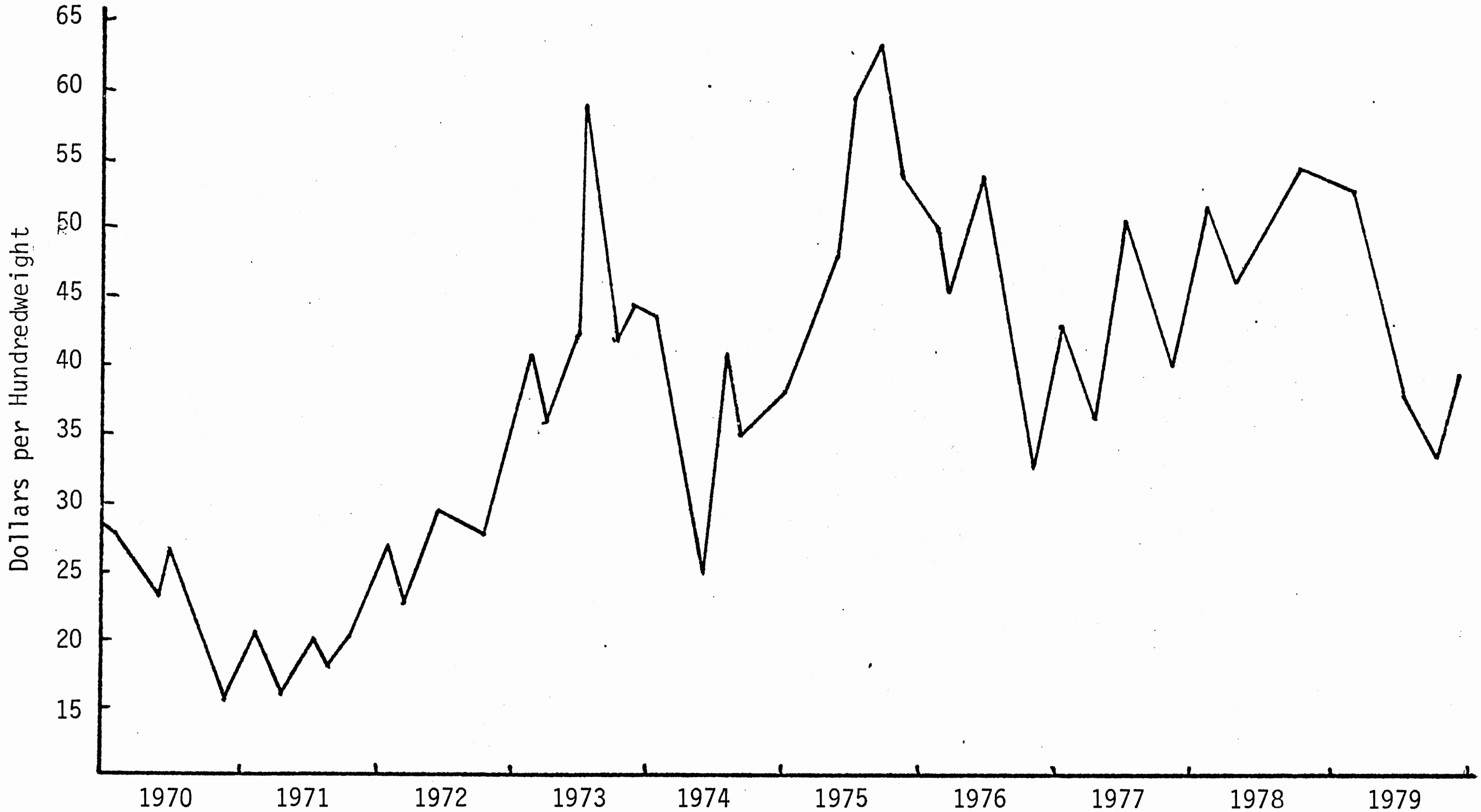

Figure 1. Market Hog Prices 1970-1979--U.S. #1 and #2 Grade, 230 Pounds, Oklahoma City Market

past as evidenced by cyclical patterns of production and prices. But, the latter course of action, holding output constant, is growing in popularity and may be the soundest strategy. Producers have gone more and more to high investment, permanent confinement facilities for hog production. Such facilities are not as amenable to variable in production levels as the more temporary pasture facilities they are replacing. In addition, producers who choose stable production levels appear to prosper and remain in business longer than do producers who opt for an "in and out" system of production.

There may appear to be a dichotomy developing between theoretical profit maximization and the actual practices of more successful producers. The reason for this difference is, however, readily discernible. The apparent contradiction centers around one of the standard assumptions of microeconomic theory--perfect knowledge. Assuming it and having it are two entirely different matters. It is one thing to assume perfect knowledge and say an entrepreneur should equate marginal revenue and marginal cost; it is quite another for a farmer living in a world of price and cost uncertainty to actually do it. The problem can be summarized as follows. Profit would, in fact, be maximized by producing at a level that would equalize marginal cost and marginal revenue. But, production lags necessitate that operating decisions be made before marginal cost and marginal revenue become known. Equalizing "expected" marginal costs with "expected" marginal revenue will not necessarily maximize "actual" profits. Expectations are often wrong. In addition, there may be production and cost efficiencies associated with a constant level of production over time. These may outweight the potential gains from output adjustments based on uncertain price and cost expectations.

Hypothesis and Objectives

Market hog prices historically have shown great variation and have often followed a cyclical pattern. Franzmann (1979) finds evidence of a four year and a twenty-eight year cycle in hog prices. Price cycles imply the possibility of forecasting long-range prices. Forecasting, in turn, suggests the opportunity to vary the production or marketing process in order to enhance profits. It is known that profit is maximized by producing where marginal cost equals marginal revenue. Since hog prices and production costs vary widely, it follows that the profit-maximizing level of production also varies.

The hypothesis which this study attempt to analyze is: A hog producer can combine price forecasts with proper decision criteria to increase profits by adjusting production to market more hogs when prices are high and fewer hogs when prices fall.

The general objective of this study is to determine which combination of management strategies and price prediction method will result in the greatest profit for a swine enterprise.

The specific objectives are to:

1. analyze the cost structure of selected swine production systems, with special consideration for systems with sufficient flexibility to allow adjustments in output levels with minimal increases in average total costs;
2. analyze various price prediction methods for accuracy and ease of use;
3. identify management strategies for selected swine production systems, which increase long-term profit by incorporating price outlook information; and

4. determine the relative gain or loss in total profit of a flexible system as compared to one which produces where average total cost is minimized.

Procedure

There are three main areas of activity in this research. The first area entails the determination of production costs for selected swine production systems and the estimation of how certain technical efficiencies of production (i.e., rate of gain, feed conversion, litter size, labor requirements, etc.) vary with different degrees of utilization of the production facilities.

The second area involves the estimation and analysis of price prediction equations. In order to make production and marketing adjustments, the manager must have some indication of future prices. Obviously, the more accurate the price forecast, the greater the probability that production adjustments will be profitable. The length of the forecast required is a function of the length of the production process.

The third area of research, and the key to this project, is the development of a dynamic swine enterprise simulation model. The model must be able to use price outlook information to determine the optimal output levels, make appropriate production adjustments, and calculate the resulting receipts and expenses for various swine systems over a prolonged simulation period.

A step-by-step listing of procedure is:

1. Identify different swine production systems and obtain cost information for selected systems.

2. Determine production and cost coefficients for each system over a range of output.
3. Develop hog price prediction models.
4. Develop management strategies which allow for production and marketing flexibility.
5. Develop a dynamic model to simulate the production and marketing process for selected swine systems with variable levels of production.
6. Incorporate price predictions as the production control mechanism in the simulation model.
7. Calculate profit for flexible production strategies and compare with non-flexible strategies for the swine systems selected.

Scope and Limitations

Williams and Plain (1978) state that the profitability of a swine enterprise on a particular farm is primarily a function of three variables: (1) general economic conditions; (2) the husbandry skills of the operator; and (3) his understanding of basic economic and farm management principles and ability to employ them in decision making.

This is a firm-level study. Consequently, no attempt is made to control or influence general economic conditions. The second variable, the husbandry skills of the operator, is outside the realm of economics and is left to the animal scientists. It is the third profit variable that is examined in this study. To what extent can a hog producer with a good understanding of economics employ theory to enhance his profits? More specifically, this research examines the management strategies which the operators use. Given a particular price forecast, what type of production changes, if any, should be made and to what extent should output vary?

A wide variety of swine production systems are used in the United States and there is virtually no limit to the number of management strategies which can be used in producing hogs. In addition, numerous methods exist to forecast hog prices. Since it is not feasible to attempt to simulate all possible combinations of these three factors (systems, strategies, and forecasts) it became necessary very early in this research project to place strict limitations in these areas. Only two production systems, six management strategies, and five price forecasting methods are examined in this study.

Perhaps the most serious limitation on this research involves the historical approach to analysis which is used. The feasibility and profitability of adaptive planning under price uncertainty is examined by studying it from an ex post viewpoint. This research tries to determine what would have been the results of adaptive planning if it had been used during the 1970s. It does not necessarily follow that tactics which either did or did not work during the past will meet with the same fate in the future.

Dissertation Organization

Chapter II presents the economic theory underlying the procedures used in this research.

Chapter III contains a description of swine production systems and the production coefficients for the farrow-to-finish enterprises which are analyzed. Also presented is the simulation model which is used to perform the analysis and five price prediction models. The prediction models provide price forecasts which the simulation model uses in making production decisions.

Chapter IV reports the results from using the model to simulate two swine enterprises. Five price forecasting methods and six different management strategies are modeled.

Chapter V summarizes the research, presents conclusions drawn from this effort, and offers some suggestions for further research.

CHAPTER II

THEORY

Introduction

Deciding the level of production is one of the most crucial decisions a manager must make. Although output is partially determined when production facilities are selected, the manager can do much in the short run to vary output without making major alterations in fixed facilities. Production can always be discontinued and frequently there is the opportunity to expand output by increasing variable inputs used in the production process.

The most frequent impetus for altering the production process is price variation. Minor changes in the price of inputs or the price of the product can lead to a major change in the most profitable output level, e.g., when revenues fall below variable costs. The key to achieving the most profitable production level is accurate projection of expected costs and returns. The outcome of a decision relative to that initially expected is dependent on the adequacy of the data on which the decision is based. Central to understanding the decision process is a knowledge of cost theory and profit maximizing criteria for an individual firm. This chapter begins with a discussion of production and price cycles. Next is a summary of economic theory of the firm. A review is presented of profit maximizing criteria and how flexibility can be used to cope with price variation. Flexibility, in this study, consists of varying sow herd size and marketing feeder pigs or slaughter hogs. This is followed by a review of investment theory and replacement models.

Production flexibility requires some criterion for making decisions about livestock sales and acquisition. This problem can be treated as a general investment decision or one of a number of specific replacement models can be utilized. The final two sections in this chapter consist of a discussion of the value of information and a summary of simulation models.

Production and Price Cycles

The main cause of hog price variation is changing supply--a large supply of hogs leads to lower prices while a small supply results in higher prices. The changing supply results largely from producers overreacting to economic incentives stemming from periodic high and low prices (Purcell, 1979). In other words, price variation is caused by variation in supply, and variation in supply is caused by price variation.

The occurrence of production cycles and price changes is shown in Figure 2 for 1970 through 1979. The graph reflects the percentage change in both hog production (as represented by commercial slaughter) and prices from one year earlier levels. It is apparent from Figure 2 that production increases are countered by price decreases and vice versa.

Periodic fluctuations in hog prices have been reported for over 80 years (Breimyer, 1959). Early attempts to explain the nature of hog price variation linked hog prices to corn production. Hogs were the main consumers of corn and in many ways the most adjustable users.

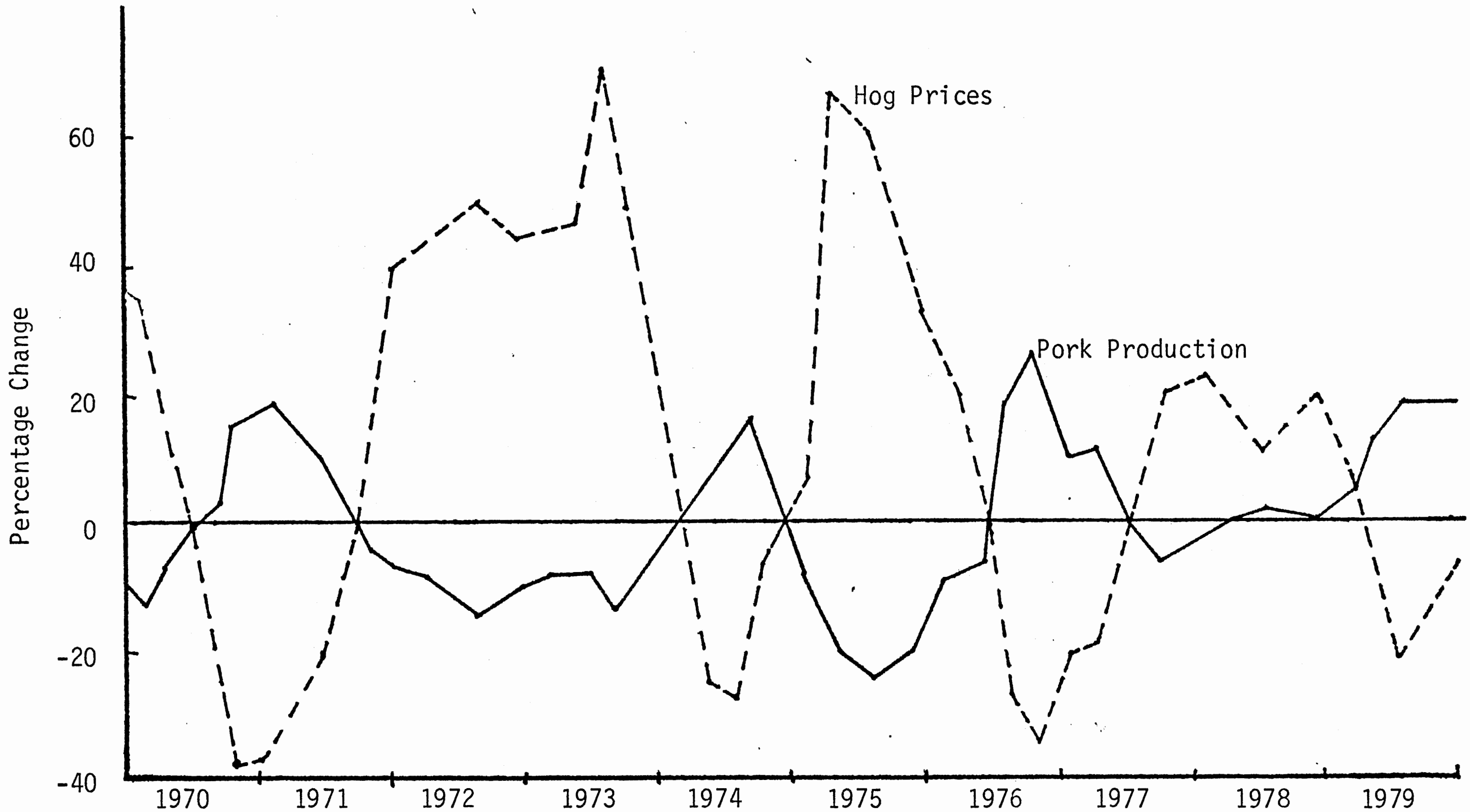

Figure 2. Percentage Change in Hog Prices and Pork Production from Previous Year's Level (1970-1979); Seven Market Average Price for Barrows and Gilts; Commercial Pork Production Per Person

Since interseasonal storage of corn was rare, years with large corn harvests were usually followed by years with large hog production and, consequently, low hog prices. Smaller corn crops led to smaller pig crops and higher hog prices. This positive correlation between corn production and subsequent hog production was credited with most of the variation in hog prices (Shepherd, 1942).

In the years since World War II, two changes have tended to weaken the link between corn production and hog prices. Yearly variation in corn production has decreased and long-term storage of corn has increased. As a result, the inducement to alter hog production in order to consume the past year's corn crop has been greatly lessened (Breimyer, 1959). Hog prices have taken on a cyclical nature that is largely independent of corn production. Emergence of a hog price cycle was reported by Breimyer in 1959 and has been reconfirmed frequently since then. Breimyer saw hog price cycles much like cattle cycles--as being caused not by outside influences, but rather by special features of the industry, such as high investment and biologically long life, reacting to the sum total of exogenous forces.

The predominant theory of why price cycles are perpetuated is the cobweb theorem. One of the first explanations of this pricing behavior was presented by Ezekiel in 1938. Ezekiel used hog prices as an example supporting the cobweb theorem. In presenting the cobweb theorem, Ezekiel states that:

> . . . classical economic theory rests upon the assumption that price and production, if disturbed from their equilibrium, tend to gravitate back toward that normal. The cobweb theory demonstrates that even under static conditions, this result will not necessarily follow (p. 279).

Three conditions were given by Ezekiel for the cobweb theorem to apply to the price equilibrium mechanism. First, production must be determined solely by the market price, i.e., producers assume current prices will continue and alter production based upon those prices. In addition, the individual assumes his level of production will not affect the market price (pure competition). Second, due to production lags, at least one full period must elapse before output can be changed. Third, price is determined by available supply. The cobweb theorem is illustrated in Figure 3.

The law of demand states that, ceteris paribus, additional quantities of a product will be purchased at lower prices, whereas the law of supply says additional quantities of a good will be produced at higher prices. If the quantity in an initial period (Q_1) is small, a relatively high price (P_1) will result. Producers react to this high price when planning their production for the next period. Anticipating a price of P_1, and assuming independence between their own production changes and market price, production in the second period is expanded to Q_2, the point where the supply curve[1] intersects P_1. However, in order to clear the market, this greater quantity must be sold at a reduced price--P_2, the point where the demand curve intersects Q_2. Individual producers again react to the current price (P_2) in deciding production for the third period. Anticipating the low price of P_2 for their product, producers reduce output to the point where the supply curve intersects P_2 and therefore produce only Q_1. This low production,

[1]Since the industry supply curve is the aggregate of individual marginal cost curves and price equals marginal revenue for an individual firm under pure competition, the producers are merely reacting by attempting to equate marginal cost and marginal revenue.

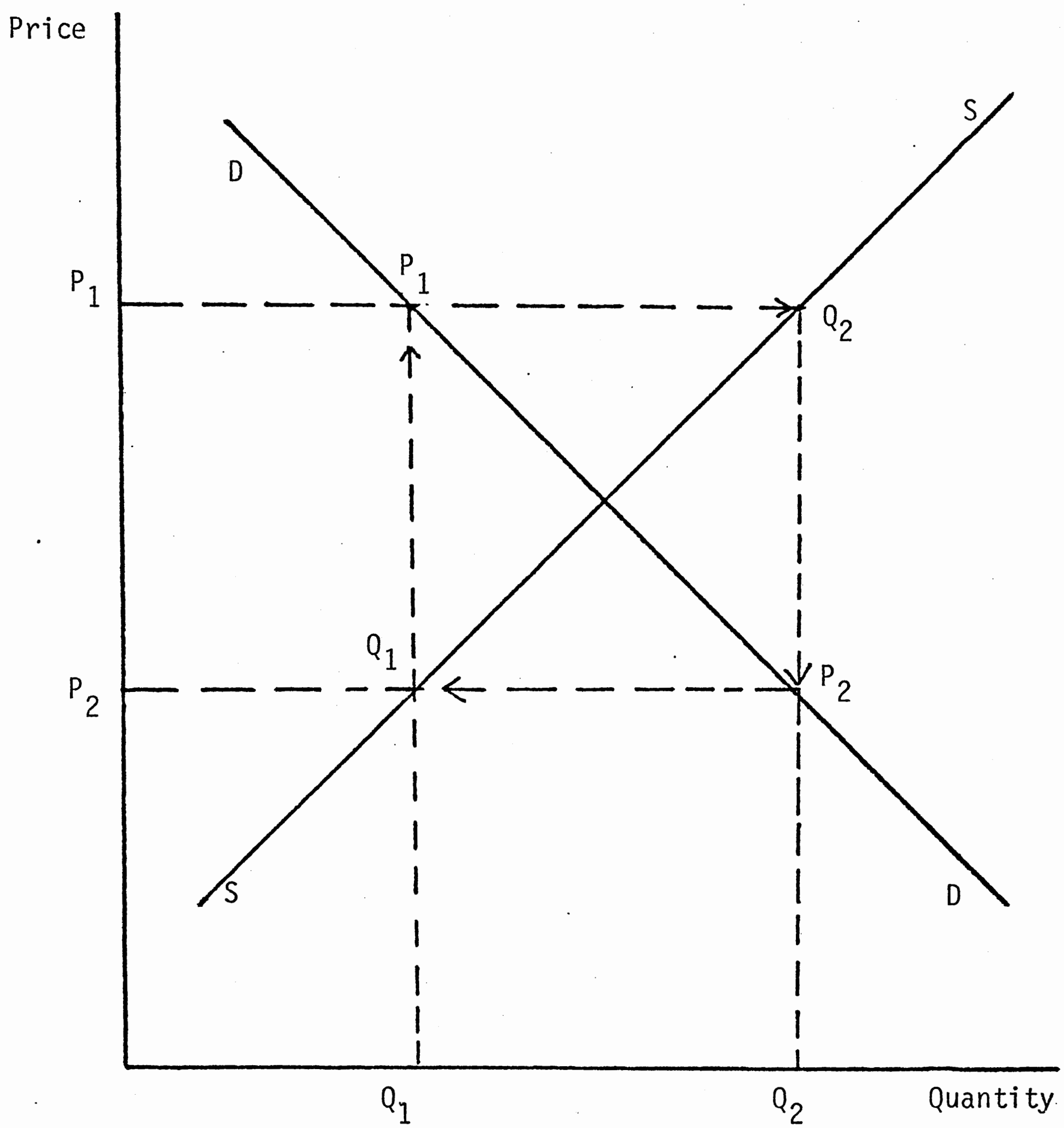

Figure 3. Cobweb Theorem: Continuous Fluctuation Case

however, corresponds to a high price on the demand curve (P_1). The process had now come full circle and is back to the initial situation with the cycle about to be repeated.

Three cases of cyclical price fluctuation can be determined in this manner: continuous fluctuation--which is the case previously discussed; divergent fluctuation--in which prices and quantity successively vary farther from equilibrium; and convergent fluctuation--in which prices and quantity successively move closer to equilibrium. Which of the three cases occurs depends upon the relative elasticities of the supply and demand curves. If the elasticity of supply is greater than the elasticity of demand, prices and quantity diverge from equilibrium. If the elasticity of supply is less than the elasticity of demand, prices and quantity converge to equilibrium. Continuous fluctuation results when the two elasticities are equal.

The cobweb theorem has received a great deal of comment since its introduction (Buchanan, 1939; Akerman, 1957; Nerlove, 1958). Talpaz (1974) discussed how multi-cyclical variation in prices can result within a cobweb theory framework. Larson (1964) described the hog cycle as true harmonic motion related to the theory of inventory cycles and arising from feedback. Still, the cobweb theorem remains central to explanations of hog price cycles.

Purcell (1979) reports an example of the cobweb theorem as it applies to the hog price cycle. During a period when prices are high and hog production appears profitable, some producers react by deciding to expand their future production. In order to accomplish this, additional gilts are retained for the breeding herd instead of being sent to slaughter. These extra gilts which are held off the market cause a decline in the supply of slaughter hogs which leads to still higher hog prices. More producers react to these higher prices, some by expanding their herds, some by entering the hog business. As the process continues the new and expanded sow herds cause sharply higher farrowings. After a period of time, the expanded pig crop reaches slaughter weight causing the supply of hogs to increase and prices to begin to fall. This marks the start of the down phase of the price cycle.

As prices fall, pork production looks less profitable. This causes some producers to decrease the number of gilts being retained for breeding and to cull marginal sows. Increased sow and gilt slaughter raises the supply of hogs and depresses prices further, causing more producers to liquidate some of their breeding stock. Eventually, the reduction in breeding herd size results in smaller pig crops reaching market. The reduction in market hog numbers causes a turn around in hog prices. The up phase of the price cycle begins and prices again move higher. Higher prices trigger an expansion in breeding herds and the cycle continues anew.

The length of a price cycle based upon the cobweb theorem is indeterminant (Talpaz, 1974). For hogs, the theoretical minimum length is equal to twice the time required to breed and farrow a sow and then raise the pigs to slaughter weight. The gestation period of a sow is 114 days and most hogs require six to seven months to reach market weight. Therefore, theoretically the hog price cycle must be at least 1.7 years in length. But the observed cycle is much longer than the biological process would indicate. Time is required for a producer to respond to prices and adjust the breeding herd (Harlow, 1960). This response lag extends the length of the cycle. During the 1970s slightly over three complete cycles in hog prices occurred, with each cycle lasting approximately three years (Plain, 1980).

Theory of the Firm in the Short Run

Diminishing returns is one of the primary foundations on which short-run microeconomic theory rests. Leftwich (1976) states the principle of diminishing returns as:

> . . . if the input of one resource is increased by equal increments per unit of time while the inputs of other resources are held constant, total product output will increase; but beyond some point the resulting output increases will become smaller and smaller (p. 150).

Diminishing returns determines the general shape of the production function and thereby marginal product (which is the slope of the total product curve) and value of marginal product (marginal product multiplied by price). Since diminishing returns describes the relationship between variable inputs and output, it also influences the behavior of the average variable cost curve and thereby marginal cost.

The formal beginnings of modern cost theory can be traced to two Frenchmen, Cournot and Dupuit (Ekelund and Herbert, 1975). Cournot, a 19th century mathematician economist, was one of the first to widely employ mathematics and graphs in expressing economic concepts. In his Researches into the Mathematical Principles of the Theory of Wealth (1838), Cournot analyzed the problem of profit maximization by a monopolistic supplier of mineral water. A monopolist can control, within certain limits, the price received by limiting production. Cournot demonstrated mathematically that, for profit (π) maximization, production should be where the change in profit due to a change in output ($d\pi/dx$) equals zero. Since profit equals total revenue (TR) minus total costs (TC), the point of profit maximization is determined by setting the derivative of the profit equation equal to zero as shown in Equation 1.

$$d\pi/dx = dTR/dx - dTC/dx = 0 \qquad (1)$$

Dupuit, a contemporary of Cournot, was a French engineer whose hobby was economics. He added the concepts of variable and fixed costs to analysis of profit maximization. Variable costs are those which vary directly with the rate of output while fixed costs are those which in the short run do not vary with output. Dupuit states that the price which a monopolist should charge in order to maximize his net returns is a function of variable costs. As variable costs increase, the profit-maximizing price increases and output decreases. Although fixed costs do not play an active role in determining the level of maximum net revenue, Dupuit realized that they must be covered in the long run if the firm is to continue to operate.

Figure 4 illustrates short-run cost curves for an individual firm under pure competition. This brief summary is based on Viner's 1931 article "Cost Curves and Supply Curves". The prices of factors used in production and the price of the product are assumed independent of the firm's output. The average fixed cost curve (AFC) is a rectangular hyperbola since it represents a constant amount (fixed costs) divided by an increasing output. The law of diminishing returns requires an increasing amount of input per unit of output as output increases beyond some point. Therefore, average variable cost (AVC) will eventually increase as output increases. The average total cost curve

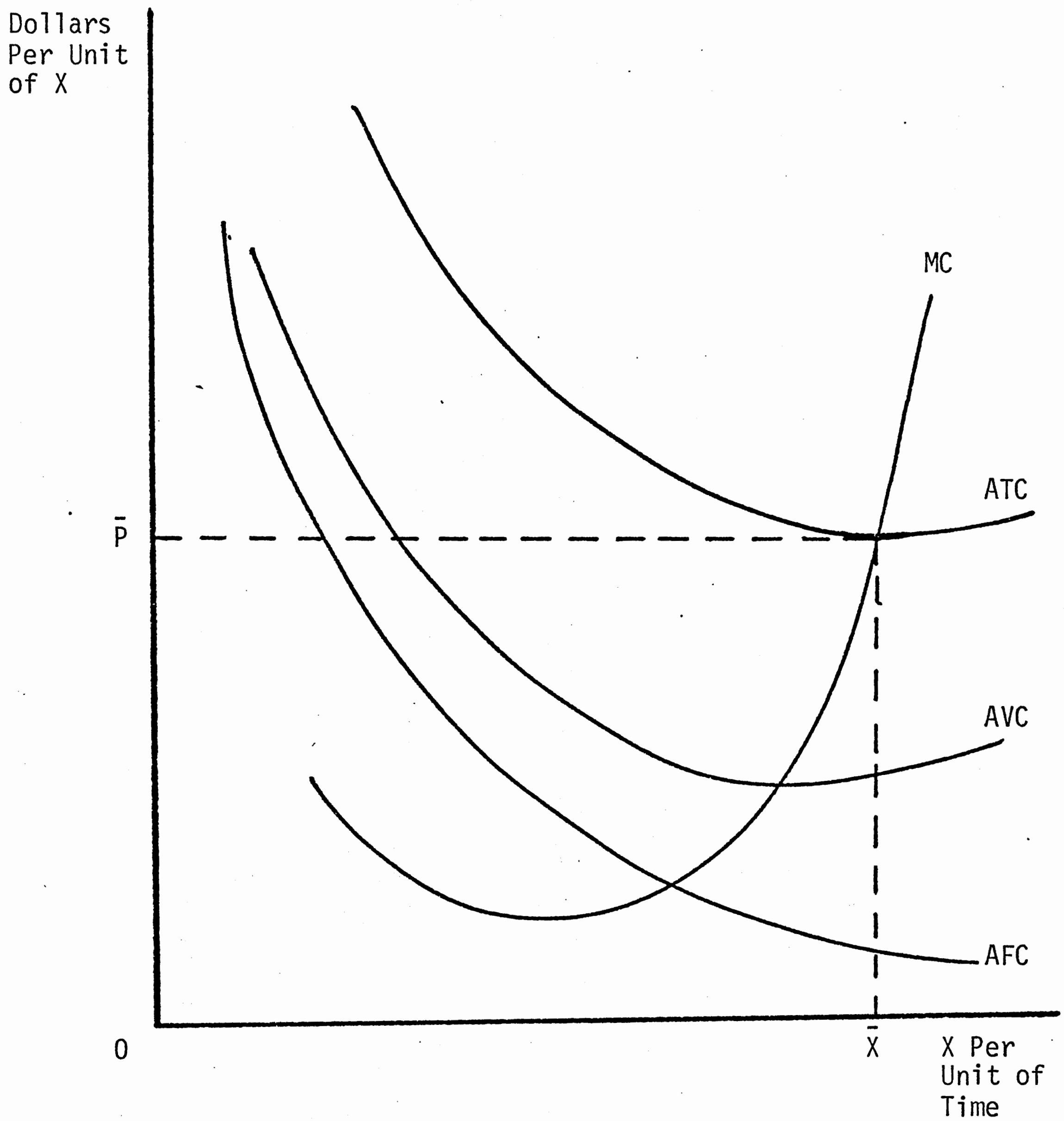

Figure 4. Short Run Cost Curves

(ATC) is a vertical summation of the average total and average variable cost curves. Relative lengths and slopes of these curves will vary from firm to firm depending upon the relative magnitude of fixed and variable costs and the degree with which the law of diminishing returns operates. The marginal cost curve (MC) represents the increase in costs as output is increased by one unit. The marginal cost curve crosses both average cost curves at their minimum points. The minimum point corresponds with price $\bar{P}$ and output level $\bar{X}$ in Figure 4.

Under pure competition the demand curve facing a firm will be a horizontal line equal to price. The firm will produce where price is equal to marginal cost, therefore the marginal cost curve represents the firm's short-run supply curve. Should the prevailing price fall below average variable costs, the firm will not produce. The short-run supply curve for the industry can be found by summing horizontally individual firms' marginal cost curves.

Short Run Cost Flexibility

An assumption commonly used in cost theory is perfect knowledge (Heady, 1952). Under this condition, the cost structure selected will be the one which gives the lowest average total cost. This would correspond to the most efficient production function. However, if the producer lacks perfect knowledge or if he knows that prices will vary regularly in the future, he may logically opt for a set of fixed resources which does not minimize expected average total costs (French et al., 1956). Instead he may select a set of facilities which incorporates flexibility into his short run cost structure. This can be accomplished by reducing fixed facilities relative to variable inputs, hence, fixed costs relative to variable costs (Stigler, 1939).

An example would be a producer choosing between two methods of production. One method involves high fixed costs but provides high initial output per unit of input (e.g., highly mechanized). The second method has lower fixed costs but is not as efficient in use of variable inputs. (When efficiency is defined as output per unit of variable input.) There two alternatives can be represented by the production functions in Figure 5 (Heady, 1952, p. 246). Curve I represents a short run production function of the first type and Curve F depicts the less efficient method of production. Marginal productivity (change in output for a one unit increase in input) is more nearly constant for Curve F. Therefore, Curve F represents a production method which is more flexible to variation in levels of output.

Figure 6 (Heady, 1952) shows the type of total cost relationship associated with these production functions. Greater curvature of the inflexible production function (Curve I) causes a corresponding curve in its total cost line. The inflexible production function (I) has higher total costs at low levels of output due to higher fixed costs, lower costs at intermediate levels of output due to more efficient use of variable inputs, and higher costs at high levels of output because of higher fixed costs and decreasing efficiency. Dividing the total costs shown in Figure 6 by their respective output yields the short run average cost curves in Figure 7 (Heady, 1952). The average total cost curve of the flexible system is flatter and higher at its minimum point than the average total cost curve of the inflexible system.

The marginal cost curves for the inflexible and flexible systems shown in Figure 7 are depicted in Figure 8. The relatively flat average

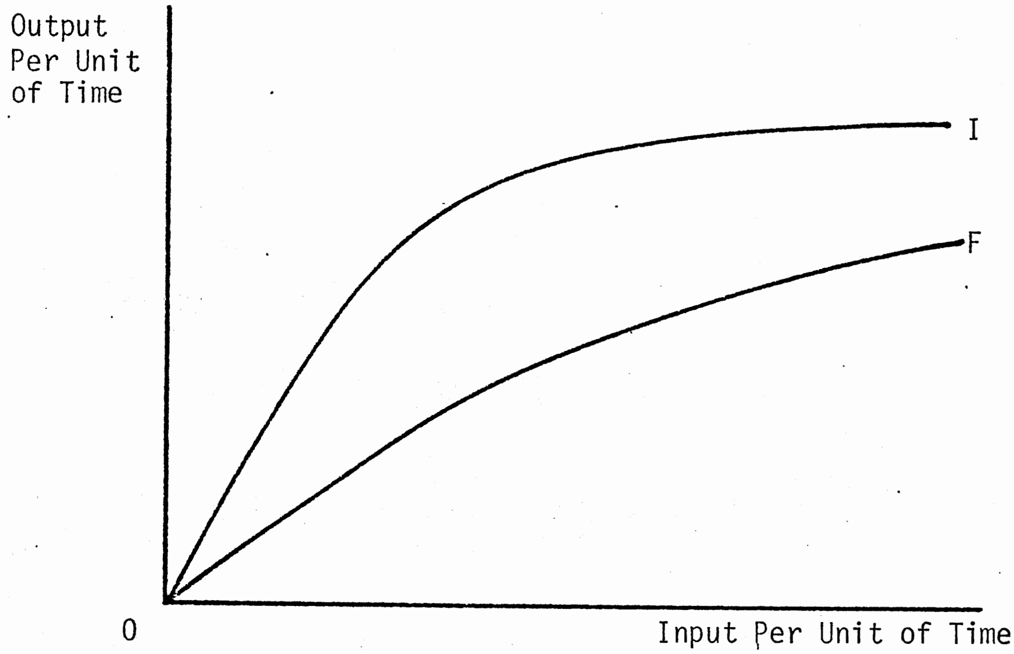

Figure 5. Production Functions for Two Firms with Different Degrees of Flexibility

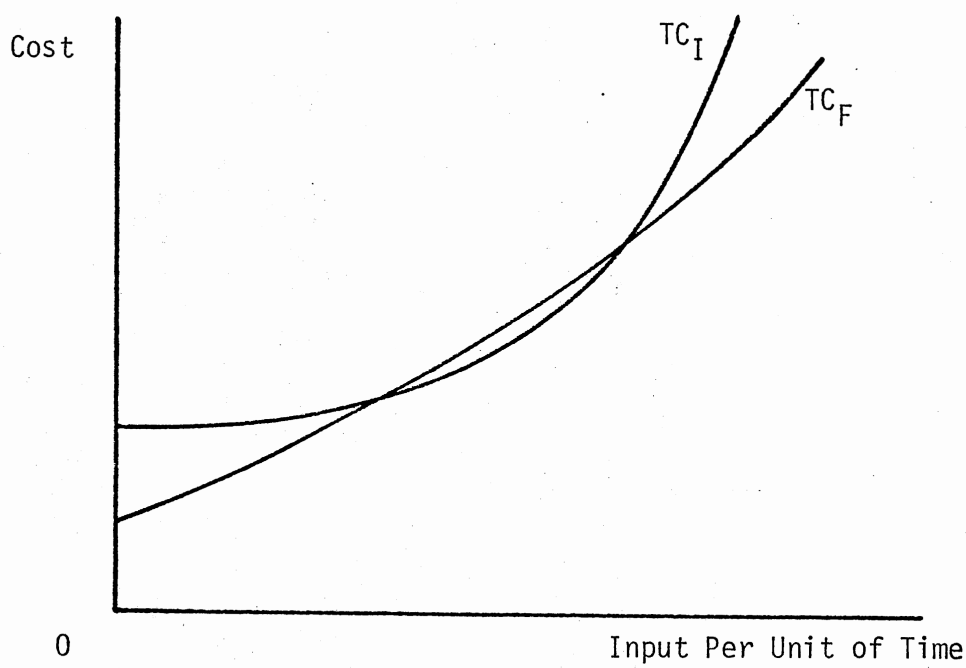

Figure 6. Total Cost Curves for Firms with Different Degrees of Flexibility

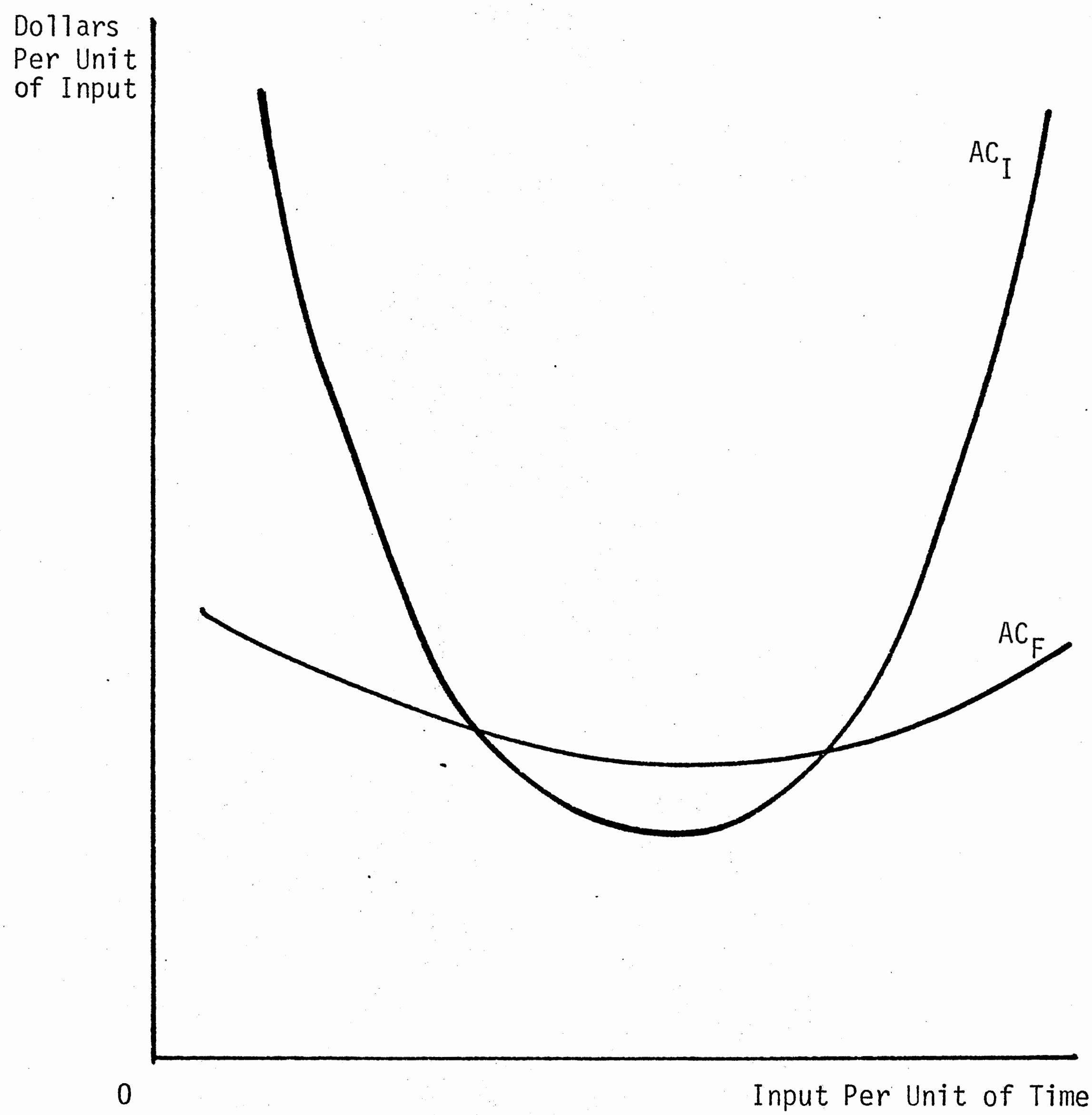

Figure 7. Average Total Cost Curves for Firms with Different Degrees of Flexibility

total cost curve of the flexible system results in a more horizontal marginal cost curve as compared to the more vertical marginal cost curve of the inflexible system. The portion of the marginal cost curve above average variable cost represents the short run supply curve for a firm. If the price of the product increases from P_1 to P_2, and the firms represented in Figure 8 respond by adjusting output to keep marginal cost equal to marginal revenue (which equals price under pure competition), then output for each firm will increase. As can be seen from Figure 8, the change in output for the flexible firm will be greater than the change in output for the inflexible firm.

Flexibility and Profit Maximization

The significance of flexibility and the consequences of changing levels of production can be illustrated using a method developed by Ikerd (1976). Profit equals total revenue minus total cost. Total revenue is equal to the price of the product times the amount produced. If total cost and the level of production are held constant, profit will vary directly and linearly with product price as depicted by π_0 in Figure 9. If the price of the product is zero, profit is equal to the negative of total costs. Profit is zero when total revenue equals total costs or at the point where price equals total cost (TC) divided by the level of production (X). The greater the price, the greater is profit. This profit function (π_0) is the type facing a firm which has constant costs and produces at a constant level regardless of product price.

As was shown earlier, profit is maximized by producing where marginal cost equals marginal revenue. Since marginal revenue equals

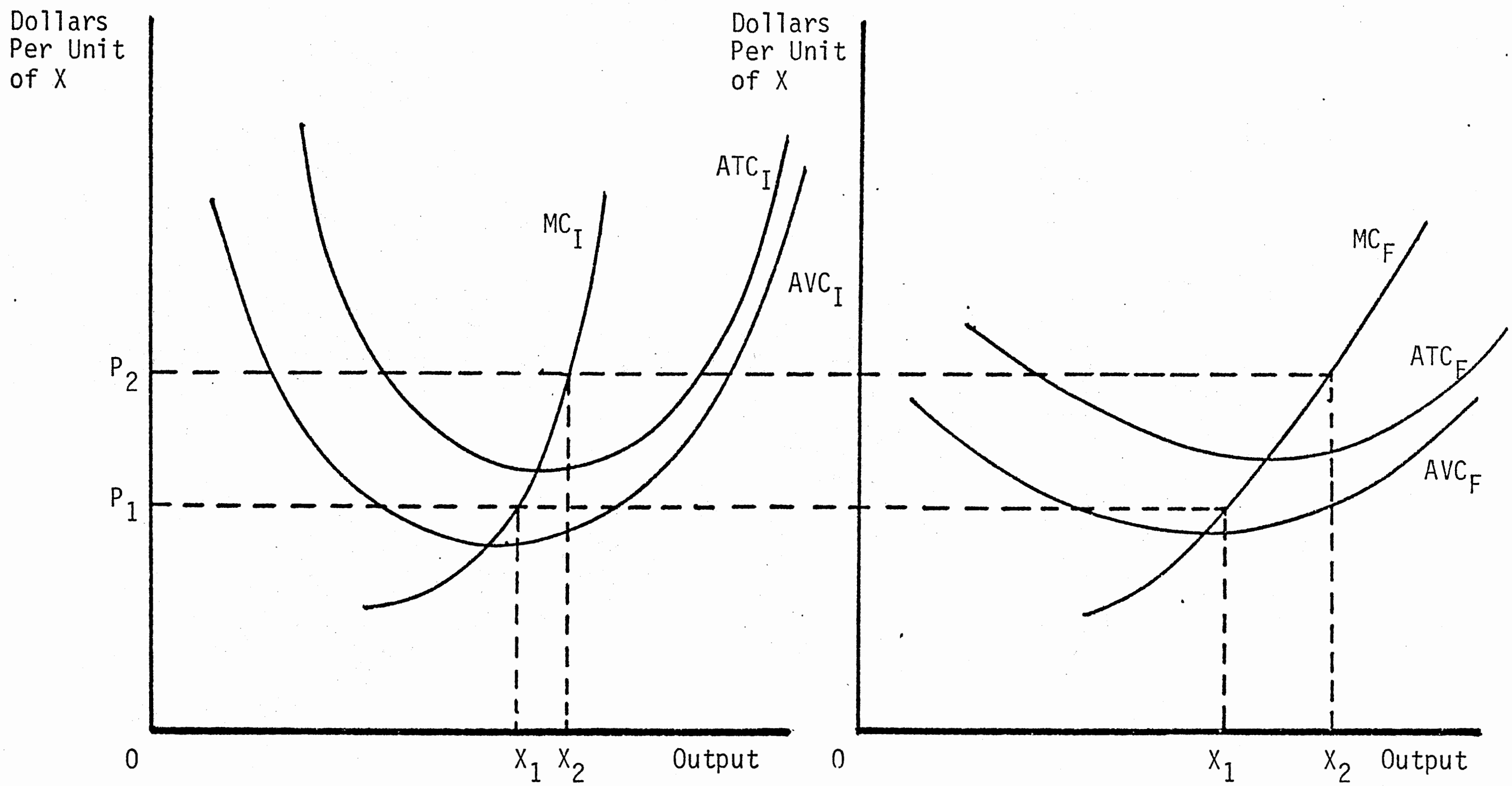

Figure 8. Changes in Output Due to Price Changes for Firms With Different Degrees of Flexibility

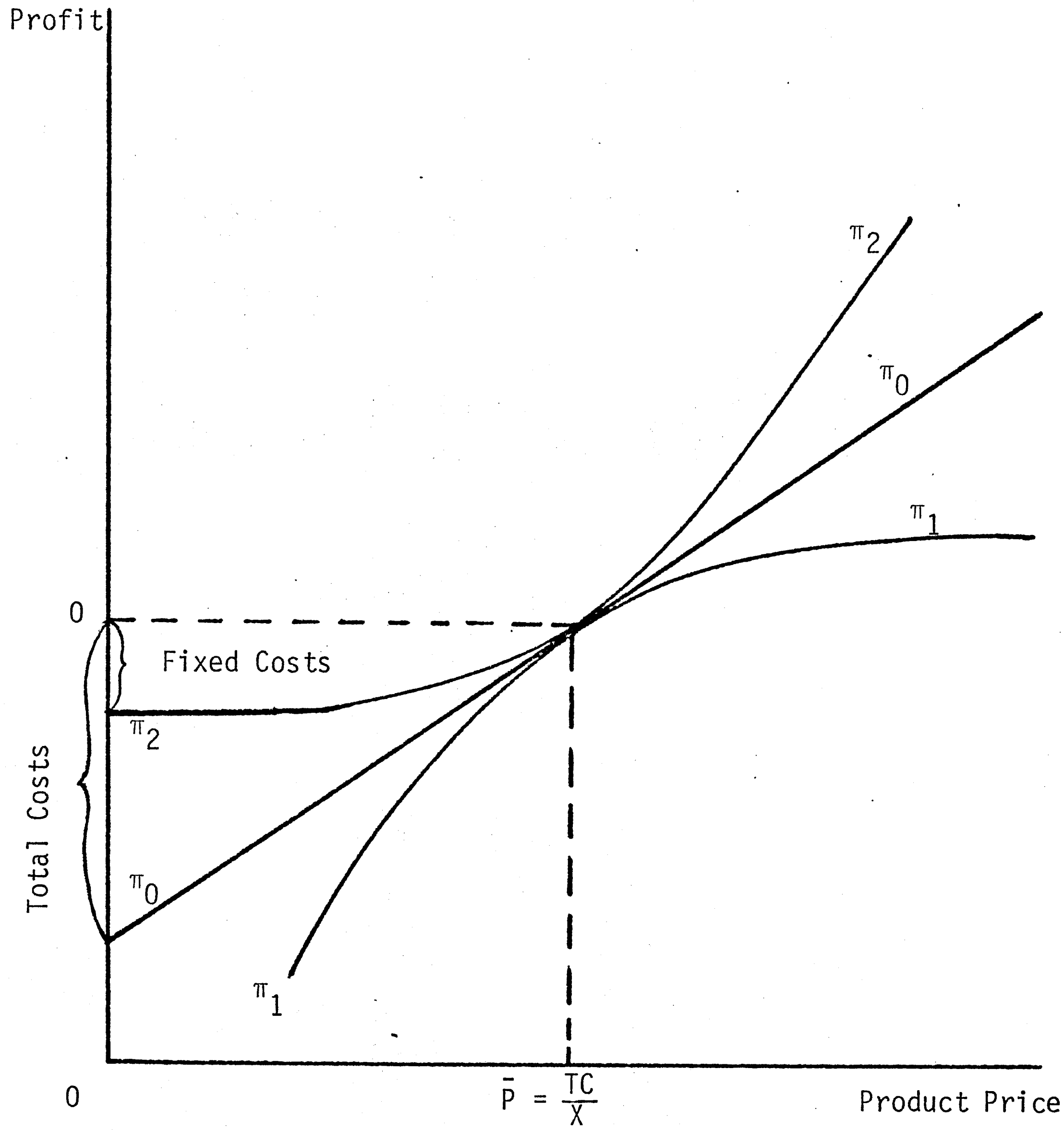

Figure 9. Relationship Between Profit and Product Price for Three Production Strategies--One Which Produces at a Constant Level (π_0), One Which Varies Output Directly with Price (π_2), and One Which Varies Output Inversely with Price (π_1)

product price for a purely competitive firm, and since product price and production cost are not closely related in the short run in swine production, it follows that output must be varied directly with product price and inversely with cost in order for a swine enterprise to maximize profits.

The effect of output variability on profits can be analyzed using Figure 9. As shown in Figure 4, the lowest cost level of production is the point where average total cost is at a minimum. If output is allowed to vary around this minimum average total cost point ($\bar{X}$) as price varies around the break-even price ($\bar{P}$), a non-linear profit curve is obtained.

Ikerd (1976) reports many farmers try to anticipate short-run price changes and adjust output accordingly to maximize profits. Production is increased if higher prices are expected and reduced when lower prices are anticipated. The existence of price cycles for many agricultural commodities indicates that producers are often wrong in their expectations, and thus increase production only to find that prices have fallen and reduce production to find stronger prices for their smaller quantities of product (note Figure 2). This is typified by the familiar cobweb theorem and is represented by profit function π_1 in Figure 9. The inverse relationship between output and prices causes a producer to profit less from both higher and lower prices than does the producer who maintains a constant level of output (π_0).

Profit function π_2 in Figure 9 also represents a producer who adjusts output to expected prices but, in this case, it is assumed that the expectations are accurate. The producer markets more product when prices are high and less when prices are low. If the price falls below the firm's minimum average variable cost, production will cease and profit will equal the negative of fixed costs for the period. At high prices profit is greater than in the previous situations due to increased production. At low prices the producer who correctly adjusts output (π_2) incurs a smaller loss (due to lower variable costs) than does the constant output producer (π_0). An even greater loss would result from a low price if a high price had been anticipated and output had been adjusted accordingly (π_1).

Assuming diminishing returns, an increase in flexibility might have two effects on the profit curve. First, the greater the change in output the firm undergoes in response to an expected change in price (yet still be producing where marginal cost equals expected marginal revenue), the greater the curvature of the profit curve. Second, there may be some costs associated with flexibility (Heady, 1952, p. 346).

For any given size of production facility, technical efficiency is enhanced by producing where average variable cost is at a minimum. For purposes of clarity, the term designed optimal output level is used to designate the minimum point on the short run average total cost curve for the expected life of the fixed facilities. Assuming the normal "U" shaped average total costs curve, changes in output from the designed optimal output level may cause average total costs to increase (Stigler, 1939). For example, increasing hog numbers beyond designed capacity drops production efficiency due to overcrowding, while decreasing numbers mean that fixed costs are averaged over fewer hogs. If the minimum average total cost of a flexible firm is higher than for an inflexible firm (note Figure 7) as it would be assuming either a loss in technical efficiency or an increase in fixed costs due to flexibility, then the profit curve of the flexible firm will be lower at the price associated with most efficient production ($\bar{P}$).

The effects of flexibility on profit can be illustrated graphically in Figure 10. If we again use the subscript I for an inflexible firm and F for a flexible firm, then the π_I and π_F profit curves in Figure 10 correspond to the average total cost curves of the flexible and inflexible firms in Figure 7. The line labeled π_0 again represents the profit curve of a firm which holds its output constant. The profit curve for an inflexible firm with the same average total costs as the constant output firm is represented by π_I. The curve π_F represents the profit of a more flexible firm which has a higher minimum average total cost than the other firms. It is assumed that both the flexible and inflexible firms make proper production adjustments in response to price changes. As can be seen from Figure 10, given changing prices the inflexible firm's profits (π_I) will exceed those of an equally efficient firm which produces a constant output (π_0). Whether the flexible firm's profits (π_F) or the inflexible firm's profits (π_I) are greatest depends upon (1) the relative curvature of the two curves, which is associated with the magnitude of their changes in output due to price variation, (2) the differences in average total cost associated with the most efficient output, (3) the frequency and magnitude of variation in price of the product, and (4) the relative accuracy of their price forecasts.

Figure 11 shows profit functions similar to those in Figure 10. One additional profit function (π_N) has been added to represent the effect of output adjustments by the flexible firm when there is a negative correlation between expected and realized prices. If, for example, the prices in two periods are P_a and P_b, the average profit

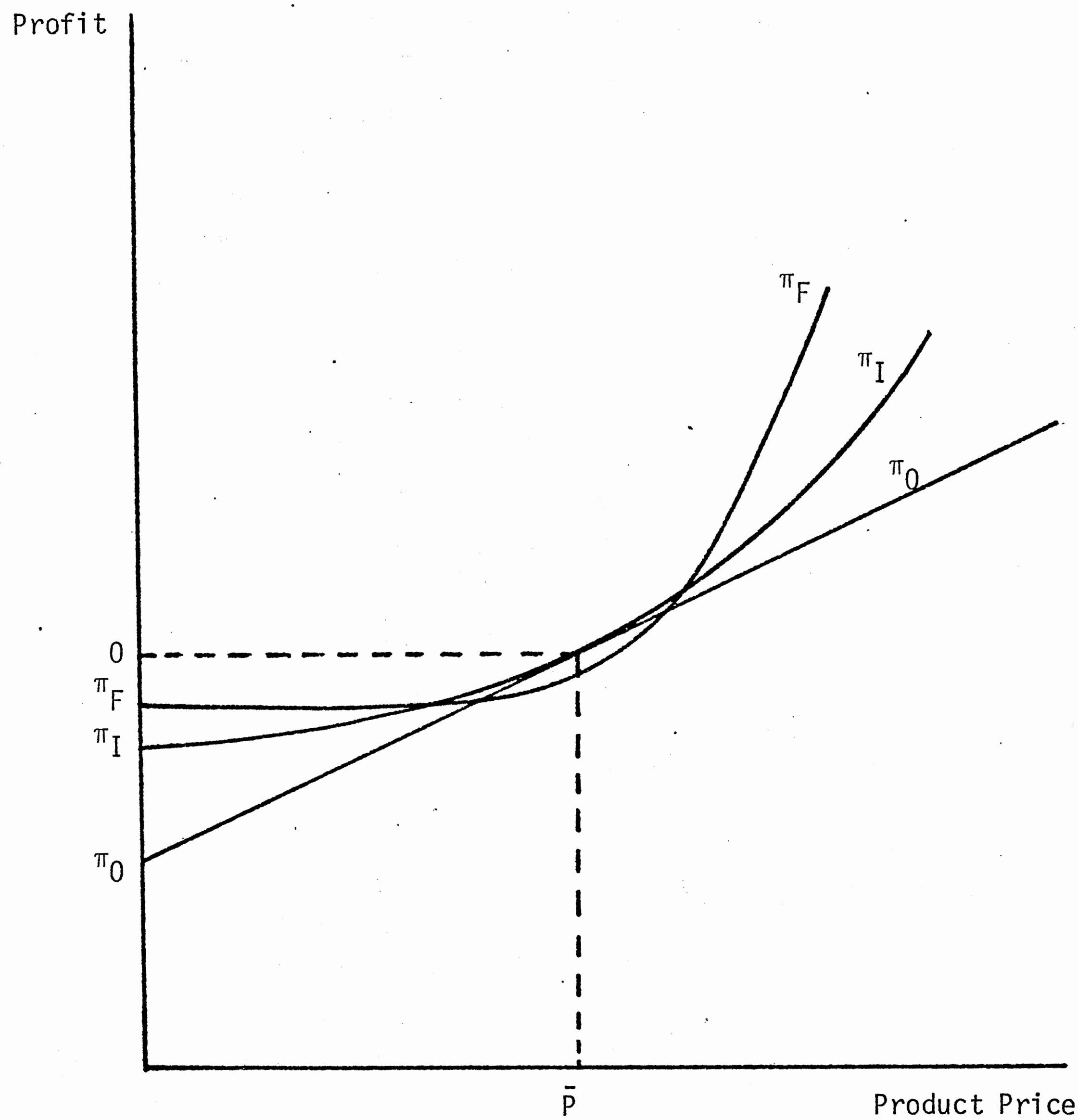

Figure 10. Profit Curve for Three Firms with Different Degrees of Flexibility--A Flexible Firm (π_F), An Inflexible Firm (π_I), and One Which Produces at a Constant Level (π_0)

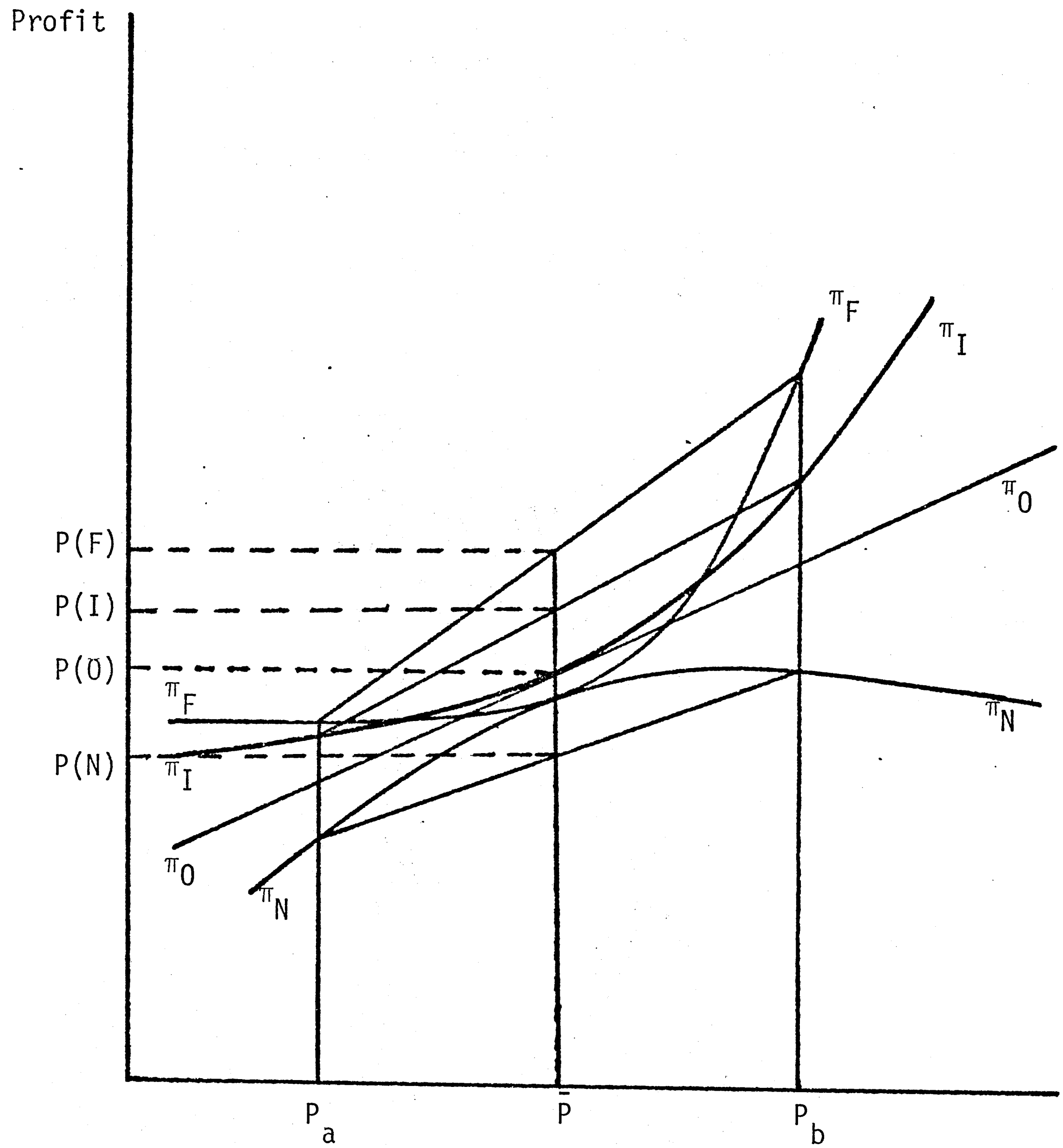

Figure 11. Average Profits for Four Firms--A Flexible and an Inflexible Firm Which Adjusts Output Directly with Price, A Firm Which Holds Output Constant, and a Flexible Firm Which Varies Output Inversely with Price

per period may be represented by the midpoint on the lines associated with the various profit functions which extend from P_a to P_b. In this case, the average profit for the flexible firm, P(F), is greater than for the inflexible firm, P(I). This implies that the profit gain from flexibility more than offset the cost advantage of the inflexible firm, The lowest profit P(N), is earned by the flexible firm which incorrectly anticipates price changes and varies output inversely with product price.

Investment Theory

There are three basic methods of analyzing investment alternatives: the payback method, the internal rate of return method, and the net present value method (Weston and Brigham, 1978).

The payback period is the number of years it takes a firm to recover its original investment. When using this method to compare investments, the project with the shortest payback period is preferred. The payback period is the easiest method to calculate but it has two serious limitations: it ignores income beyond the payback period and it fails to take into account the time value of money.

The internal rate of return is defined as the interest rate that equates the present value of the expected future net cash flows, or net receipts, to the initial cost outlay. Projects are profitable if the internal rate of return is greater than the relevant cost of capital. The internal rate of return method overcomes both of the disadvantages of the payback method. However, it is much more difficult to calculate and the decision criteria is based solely on a rate of return, rather than the magnitude of profits.

The net present value is the present value of the expected net cash flows of an investment, discounted at the cost of capital, minus the initial cost outlay of the project. Desirable investments are those which have a positive net present value. The greater the net present value, the more desirable is the investment. The net present value method also overcomes both drawbacks of the payback method and is easier to calculate than the internal rate of return. For short term investments which do not require discounting, the net present value becomes simply receipts minus expenses. The net present value method is used to evaluate investment decisions in this research.

Replacement Models

Replacement models are used to determine the optimum time to replace capital assets. Faris (1960) classifies assets to be examined into three categories based upon the length of the production process and frequency of sales. Although there are major differences between the three categories, their replacement criteria is similar. The optimum time to replace an asset is when its marginal net revenue is equal to the highest amortized present value of anticipated net revenue from the following asset.

Once the basic replacement criterion has been established, various modifications can be made in the models to adapt them to more specialized circumstances. Chisholm (1974) presents a cost minimization equipment model which incorporates tax considerations. Kletke (1969) developed a policy for replacement with a non-identical asset. Ciriacy-Wantrup (1963) adjusted for discount rate to account for risk and uncertainty. A framework for determining replacement patterns for assets with uncertain production lengths was presented by Burt (1965).

Since reality includes such variables as risk, taxes, and changing prices and technology, it is reasonable that these factors be included in replacement models. However, adding these elements can greatly increase the complexity of the model. The relative value of this trade-off between increased accuracy and added complexity must be weighed by the decision maker when selecting the type of replacement model to use.

Although replacement models are very precise, they have one very serious limitation. Replacement models require long-range price forecasting. Current net revenue is compared to anticipated average net revenue of the proposed replacements. In the case of sow replacement, a multi-year forecast of both hog and feed prices would be required. The accuracy of hog or feed price forecasts for several years ahead is highly questionable, at best.

Value of Information

Information only has value in an uncertain environment. Given the many uncertainties of life and business it is no wonder that information is such a sought-after commodity. The economics of information relating to price discovery was analyzed by Stigler (1961). He described price search as a function of three variables: the fraction of the buyer's expenditures going for the commodity, the frequency of the transaction, and the geographical size of the market. Eisgruber (1978) identified two different approaches to determining the value of information, the net social benefit approach and the decision theoretic approach.

The net social benefit approach to determining the value of information was developed by Hayami and Peterson (1972). Net social benefits are equivalent to social benefits minus social costs. Social benefits can be described as the area under the demand function and social costs as the area under the supply function. Inadequate information is equivalent to a shift in the perceived supply and demand functions and therefore affect net social benefit. This approach attempts to determine the value of information to society whereas the decision theoretic approach determines the value to the user.

The decision theoretic approach estimates the impact of information on the decision process and then places a value on the information in terms of its benefit to the decision maker. The approach assumes the decision maker is faced with a number of possible future states of nature which may occur. The outcome is uncertain but subjective probabilities for the states of nature are known. A variety of courses of action are available to the decision maker with the results depending upon the action taken and the actual situation which occurs. If additional information becomes available Bayes' Rule can be used to modify the probabilities. The value of the information is calculated by comparing the expected returns from the optimum actions determined using the additional information with the expected returns from the actions selected prior to the information becoming available. This decision theoretic method was used by Baquet et al. (1976), to determine the value of frost forecasts to orchard operators. Williams (1976) and Bullock (1972) also used the decision theoretic approach to determine the value of price outlook information to cattle feeders.

A modified form of the decision theoretic approach is used in this study. Rather than using Bayes' Rule, separate simulations are performed with results dependent upon the price forecast which is used.

The net returns from the different simulations are compared to determine the relative profitability of using each forecasting technique.

Simulation Models

Anderson, Dillon, and Hardaker (1977, p. 267) define the term simulation as "the numerical exploration of a symbolic model, used to mimic the behavior of a modeled system over time." Simulation is a valuable technique of analysis which can be applied to a wide variety of situations. It is frequently used in firm studies and has often been applied to swine research. Blackie and Dent (1976) developed a simulation model to analyze the feasibility of using only gilts in the breeding herd and to study the effects of high and low density rations on rates of gain and production costs. Lines (1979) used a simulation model to analyze the desirability of including swine operations in various farm organizations. Davis and Connor (1977) studied hog processing plant design and operation by using a simulation model.

This research uses simulation to model a farrow-to-finish swine enterprise. The model is used to examine the effects of adaptive planning when different sources of price information are used. In a somewhat similar effort, Bentley and Shumway (1981) used a simulation model to examine adaptive planning in cow-calf enterprises.

The purpose of this chapter is to briefly present some of the basic economic theory that underlies this research. The next chapter explains the methodology and assumptions and presents the simulation model used in this study. A detailed description of the two farrow-to-finish systems modeled is also included.

CHAPTER III

THE MODEL

Introduction

The economics of adaptive planning under price uncertainty is analyzed by using a computer model to simulate selected production and marketing strategies. The computer model is designed to simulate over 20 different management strategies, three types of swine enterprises, two production systems, and five price forecasting techniques. The model is capable of simulating any production period for which adequate price and production data is available. In this study a ten year period beginning in January, 1970, is examined.

A long simulation period is required in order to effectively determine the results of production and marketing strategies over a wide variety of market conditions. The ten year period examined includes slightly over three complete cycles in hog prices. An even longer simulation period would offer a better test of adapative planning but was decided against for three reasons. First, the earlier the simulation period begins, the more difficult it is to obtain accurate data on input costs. Second, the longer the simulation period, the more tenuous becomes the assumption of a constant level of technology. And third, if a very long production period is used, all facilities and equipment will be depreciated and replaced. This would move all costs into the variable cost category and tend to replace management strategies with proper selection of facilities as the primary determinant of firm profits.

Following the introduction to this chapter are two sections which describe the common swine production enterprises and systems found in the United States. Next is a section which presents selected strategies for managing a swine enterprise. The management strategies are designed to allow a decision maker to take advantage of changes in hog prices by varying the level of production. In order to profitably do this, the operator must properly anticipate price changes. The next section contains a discussion of five prediction models which can be used to forecast hog prices. A detailed description of two farrow-to-finish swine enterprises follows in the next section. Included are the production assumptions, variable cost data, and fixed facilities and costs associated with a 40 sow pasture and a 90 sow confinement system.

The final portion of the chapter describes the simulation model that is used to make production and marketing decisions for the two farrow-to-finish swine enterprises. The model incorporates the price prediction models and management strategies to analyze the profitability of adaptive planning under price uncertainty.

Swine Enterprises

Commercial swine production can be divided into three basic types of enterprises. These are (1) farrow-to-finish, (2) feeder pig production, and (3) finishing purchased pigs. The farrow-to-finish enterprise is suited to farms where swine production is either a primary of secondary enterprise (Williams, Luce, and Bloome, 1978). Labor to farrow sows, adequate feed and capital to carry hogs through the finishing phase, and availability of markets for slaughter hogs are required.

The feeder pig production enterprise may be found on farms where the manager has the desire, ability, and labor to produce pigs, but does not have adequate capital or feed availability for a farrow-to-finish swine production enterprise. The enterprise is adaptable to grain deficit areas but should be located where good markets exist for feeder pigs. The feeder pig production system provides considerable flexibility with respect to labor. Farrowings can be planned for periods when labor is not fully utilized.

Bache and Foster (1976, p. 4) identify disadvantages associated with feeder pig production as:

(1) Profits are variable for feeder pig production. The bid price received for feeder pigs is based on future profit expectations of a hog feeder. If the possibilities for profits appear high, then the bid price for feeder pigs is higher. If profit expectations appear low for the hog feeder, then the bid price is decreased. The pig producer may reap excellent gains with strong feeder pig prices or incur losses in give-away periods.

(2) The demands on management, husbandry skills, and labor are extreme for this phase of the swine industry.

(3) The market for feeder pigs is generally less competitive than the slaughter hog market. A small producer with no access to graded pig sales may not receive the prevailing market price received for graded pigs of comparable quality.

(4) A feeder pig producer may encounter problems in breeding for improved carcass merit. First, if replacement gilts are purchased, the pig producer may have little input or knowledge concerning the breeding of the purchased gilts. Secondly, the producer is not able to evaluate performance of the pigs he produces during the finishing phase.

The feeder pig finishing enterprise may be found on farms with surplus seasonal labor, adequate short term capital, economical sources of feed, and a manager knowledgeable in both hog and feed marketing. An economical source of good feeder pigs is crucial.

Swine Production Systems

Two basic swine production systems are found in the U. S.--confinement and pasture. Some producers use a combination of the two systems. The confinement system is synonymous with capital intensity and with relatively low labor requirements. The system consists of specialized buildings and rather sophisticated equipment. Typically associated with the confinement system are permanent structures, automatic feed distribution, a lagoon, self-cleaning floors, and automatic heating, cooling, and ventilation equipment. Pigs in confinement systems usually spend most, if not all, of their lives indoors.

The pasture production system is typically associated with low investment costs in portable or temporary facilities and high labor requirements. Hogs are raised on pastures and dirtlots. The primary advantage of a pasture swine production system is the relatively small investment required compared to confinement systems. Swine production on pasture also provides considerable flexibility with respect to expansion of the swine operation. Pasture systems provide an opportunity to gradually phase into hog production. The pasture system allows the operator to develop necessary management skills before expanding into an operation that requires more capital and intensive swine management. Young producers or farmers adding a swine enterprise often choose a pasture production system.

Confinement systems, on the other hand, require less labor per animal unit, thereby allowing one person to operate a larger enterprise. In addition to requiring less labor, the working conditions and agreeableness of the labor are superior to the pasture system. Compared to pasture systems, confinement systems usually have greater litter size, higher feed efficiency and faster rates of gain. Chronic diseases can pose serious problems in confinement systems due to the close proximity of the pigs.

Although the model is designed to simulate all three types of swine enterprises for both pasture and confinement systems, the only analysis reported herein is for farrow-to-finish swine enterprises. Both the pasture and the confinement farrow-to-finish enterprises are modeled.

Management Strategies

The computer model is used to simulate six different management strategies for farrow-to-finish swine enterprises. The six strategies are:

A. Constant production at design capacity

B. Optional feeder pig sales

C. Optional reduction in sow numbers below design capacity

D. Optional feeder pig sales and reduction in sow numbers (B and C)

E. Optional feeder pig sales and optional increases in sow numbers above design capacity

F. Optional feeder pig sales, optional feeder pig purchases, and optional increases and decreases in sow numbers.

In this study, design capacity refers to two groups with 20 farrowing sows per group and the pigs which each group produces (approximately 160) for the pasture system, and three groups with 30 farrowing sows per group and their pigs (about 255 per group) for the confinement system. These sizes were selected for two reasons. First, during periods of peak labor demand the enterprises require most of one worker's labor. Second, obtaining cost and production data for enterprises of this size is facilitated because they are typical of farrow-to-finish swine enterprises found in the U. S.

Management strategy A is a nonflexible strategy. With this option, the sow herd is always maintained at design capacity and all pigs produced are kept until 230 pounds, at which time they are either marketed or added to the breeding herd. This is a passive management strategy since prices do not affect the production decisions of the enterprise. The other decision strategies allow the system to respond to price expectations by being flexible in one of three ways--production, or marketing, or both.

Strategy B allows the model to market 50 pound feeder pigs if this appears more profitable than feeding them to slaughter weight. Strategy B does not allow sow numbers to vary from capacity. Strategy C allows the sow herd to be reduced below, but not expanded above, the design capacity level. Reduction in sow numbers occurs whenever variable costs of producing market hogs are greater than expected revenues from marketing those hogs. Feeder pig sales are not permitted in Strategy C. The remaining strategies combine both production and marketing flexibility by allowing variation in sow numbers and optional feeder pig sales.

Strategy D allows sale of feeder pigs and variation in sow herd size from the design capacity level down to zero. Strategy E allows sales of feeder pigs and expansion in sow herd size from the design capacity level up to an additional ten sows in each farrowing group. The pasture and confinement systems are allowed to expand to 30 and 40 farrowing sows per group, respectively. Strategy E does not allow the sow herd to be reduced below design capacity. The greatest amount of flexibility is offered by Strategy F. This strategy allows feeder pig sales, purchases of feeder pigs, and variation in sow herd size from zero to design capacity plus ten sows per group.

Price Predictions

Several price forecasting techniques are used in this study. Separate simulations are performed with decisions dependent upon price forecasts made by the different prediction methods. The net returns from the simulations are compared to determine the relative profitability of using each price forecasting technique. Although determining the value of information is not the specific purpose of this research, inferences can be drawn about the relative value to the decision maker of the different price prediction methods simulated.

There is no need to incorporate market outlook information into the decision process if a producer follows the nonflexible management strategy (Strategy A) since the facilities are always maintained at full productive capacity. The five other management strategies, however, require incorporation of outlook information or price expectations in making production and marketing decisions. To make the determination on sow herd size and feeder pig sales or purchases, the model employs price forecasts to estimate the future price of feeder pigs and market hogs. Three forecast lengths are analyzed: 16, 32 and 46 weeks. A 16 week forecast of market hog prices is utilized in making the feeder pig purchasing and marketing decisions. This forecast period was selected because it approximates the time required to finish 50 pound feeder pigs to slaughter weight (230 pounds). The sow herd size decision is based upon a combination of a 32 week forecast of feeder pig prices and a 46 week forecast of market hog prices. Thirty-two weeks approximates the time needed to produce feeder pigs. The longer period, 46 weeks, is equal to the usual time required to breed and farrow a sow and then feed the pigs to 230 pounds.

Perfect, Naive, and Futures Market Predictors

Five different types of price forecasts are used. The first is a perfect price predictor. In this version the actual historical prices for hogs are used to make the flexibility decision, i.e., production and marketing. Information on hog prices was obtained from Livestock, Meat, Wool Market News (1970-1980). Market hog and sow prices used are the weekly average of Oklahoma City prices for U. S. #1 and #2 grade 230 pound barrows and gilts and 400 pound sows. Feeder pig prices are based on weekly average quotations for 50 pound pigs on southern Missouri markets. Oklahoma City prices for sows and market hogs were not available from this source for 1970. Estimates of 1970 prices were obtained by adjusting Kansas City prices. The price per pound of 325 pound nonbreeder gilts is estimated as 90% of the market hog price. The price of 425 pound boars is calculated as 80% of the price of sows.

The second type of price predictor is the "naive" predictor. The "naive" predictor assumes future hog prices will be the same as when the decision is made, i.e., prices will not change from current levels.

The third predictor uses live hog futures contract prices quoted from the Chicago Mercantile Exchange as the basis for decision making. Two series of hog futures prices are utilized. The first involves the current futures market price for delivery 16 weeks into the future while the second is the futures market price for delivery in 46 weeks. The futures prices are adjusted for an Oklahoma City basis using average slaughter hog basis estimates reported by Ikerd (1978). Two variations are tested using the futures market as the price predictor. The model is simulated once without hedging and once with the pigs being hedged. Production and marketing decisions are based upon the futures market price predictions in both cases. A brokerage fee is charged when a hedge is initiated.

Two price prediction equations were developed as the fourth and fifth predictors and tested using the simulation model--a cyclical predictor and a causal predictor. In both cases ordinary least squares regression was performed and then a Cochrane-Orcutt procedure was used to correct for first degree autocorrelation. According to Dutta (1975), the presence of autocorrelation among disturbances does not affect the unbiased and consistent properties of ordinary least squares regression. However, the presence of autocorrelation makes the OLS estimators less efficient. That is, they do not have the least variance of the class of linear unbiased estimators. Therefore, correcting for autocorrelation results in "better" estimates.

Cyclical Predictor

Often in using time series forecasting methods, the variation of the dependent variable is separated into four components: trend, seasonal, cyclical, and an irregular component. Spectral analysis was performed on 522 weeks of 1970's hog price data as the first step in developing a cyclical predictor. Results indicate numerous cycles of very short length, cycles of approximate lengths of six months and one year, a strong cycle of length 130 weeks (2.49 years), and an even stronger cycle of length 525 weeks (10.06 years).

A harmonic analysis similar to that used by Abel (1962) was used in a regression equation to predict hog prices. Harmonic analysis utilizes sine and cosine functions to model cyclical variation over time. Two different cycle lengths (26 weeks and 52 weeks) were tried in testing for a seasonal component. The results obtained using the

26 week seasonal variation are superior to those using a 52 week season. Trial cycle lengths varying from 2.5 years to 4.2 years were tried in attempts to determine a cyclical component in the data. The harmonic regression equation used is presented in Equation 1.

$$P_t = \beta_0 + \beta_1 t + \beta_2 \sin \frac{2\pi t}{S} + \beta_3 \cos \frac{2\pi t}{S} + \beta_4 \sin \frac{2\pi t}{C} + \beta_5 \cos \frac{2\pi t}{C} + \text{Error} \tag{1}$$

The variables are defined as:

P_t = average weekly market hog price in dollars per hundredweight at time t; t = 1, 2, ..., 522

β_i = regression parameters; i = 0, 1, ..., 5

t = linear time trend in weeks (first week of 1970 equals one)

S = seasonal length

C = cycle length

The highest R^2 value (0.7024) was obtained by using a cycle length of 2.75 years, slightly longer than indicated by the spectral analysis. Results of the regression analysis are presented in Table I.

In response to the results from the spectral analysis and to account for the general shape of the data a second, longer cycle is incorporated in the harmonic regression model. The form of the revised price predictor is given in Equation 2.

$$P_t = \beta_0 + \beta_1 t + \beta_2 \sin \frac{2\pi t}{S} + \beta_3 \cos \frac{2\pi t}{S} + \beta_4 \sin \frac{2\pi t}{C_1} + \beta_5 \cos \frac{2\pi t}{C_1} + \beta_6 \sin \frac{2\pi t}{C_2} + \beta_7 \cos \frac{2\pi t}{C_2} + \text{Error} \tag{2}$$

The variables are defined as:

P_t = average weekly cash price in dollars per hundredweight at time t

β_i = regression parameters; i = 0, 1, ..., 7

TABLE I

TRACKING MARKET HOG PRICES (1970-1979) USING A HARMONIC REGRESSION EQUATION*

S (weeks)	C (weeks)	C (years)	R^2
52	219	4.2	0.555808
52	209	4.0	0.552030
52	188	3.6	0.541276
52	183	3.5	0.543940
52	170	3.2	0.594106
52	157	3.0	0.652712
52	151	2.9	0.675230
52	146	2.8	0.687276
26	146	2.8	0.700721
52	143	2.75	0.688657
26	143	2.75	0.702407
52	141	2.7	0.686664
26	130	2.5	0.658118

*No correction was made for autocorrelation of residuals.

t = linear time trend in weeks; $t = 1, 2, \ldots, 522$

S = 26 weeks (six month seasonal length)

C_1 = 143.5 weeks (2.75 year short cycle length)

C_2 = long cycle length

Trial period lengths varying from 8.8 to 10.1 years were fitted in combination with a seasonal variation of 26 weeks (six months) and a short cycle length of 143.5 weeks (2.75 years). Although there is only minor variation in the R-squared values for different long cycle lengths, the highest value (0.877881) is obtained by using a long cycle length of 470 weeks (9.0 years). Results of the regression analysis are given in Table II. The harmonic regression price predictor presented in Equation 2, using a 26 week seasonal length and two cycles with lengths of 2.75 and 9.0 years, is used to predict market hog prices for the cyclical predictor.

Feeder pig prices are also predicted by harmonic regression using an equation with the form of Equation 2. The same seasonal length (26 weeks) and cycle lengths (2.75 and 9.0 years) used in predicting market hog prices are used in predicting feeder pig prices. The results of the regressions performed on market hog and feeder pig prices are given in Table III. Both the coefficients from the ordinary least squares regression and the estimates obtained after correcting for first degree autocorrelation are presented.

Causal Predictor

The fifth predictor, a causal model, attempts to duplicate a cause and effect relationship among real world phenomenon. Although price is determined by both supply and demand, the models tested in this study

TABLE II

TRACKING MARKET HOG PRICES USING A HARMONIC REGRESSION EQUATION*

S	C_1		C_2		
(weeks)	(weeks)	(years)	(weeks)	(years)	R^2
26	143	2.75	527	10.1	0.876050
26	143	2.75	522	10.0	0.876299
26	143	2.75	517	9.9	0.876540
26	143	2.75	501	9.6	0.877190
26	143	2.75	496	9.5	0.877374
26	143	2.75	480	9.2	0.877778
26	143	2.75	475	9.1	0.877850
26	143	2.75	470	9.0	0.877881
26	143	2.75	464	8.9	0.877865
26	143	2.75	459	8.8	0.877745

*No correction was made for autocorrelation of residuals.

TABLE III

TRACKING HOG PRICES (1970-1979) USING HARMONIC REGRESSION EQUATIONS

Parameter	Before Correcting For Autocorrelation		After Correcting For Autocorrelation	
	Estimate	t-test	Estimate	t-test
Market Hog Prices:				
β_0	23.60	54.24	24.62	11.23
β_1	.0562	37.01	.0526	7.09
β_2	2.042	8.20	1.946	5.81
β_3	.8166	3.28	.8376	2.51
β_4	5.175	20.19	5.019	4.33
β_5	3.677	14.60	3.723	3.20
β_6	-3.304	10.06	-3.878	2.29
β_7	-5.647	22.01	-5.289	3.81
R^2	0.8786		0.9174	
Feeder Pig Prices:				
β_0	39.97	28.63	41.75	7.30
β_1	.1077	22.12	.1012	5.15
β_2	.6345	0.79	.3756	0.28
β_3	-6.137	7.69	-6.080	-4.49
β_4	13.39	16.28	13.31	4.02
β_5	13.73	17.00	13.88	4.22
β_6	-5.370	5.10	-6.428	-1.46
β_7	-7.760	9.43	-7.233	-2.05
R^2	0.7533		0.7620	

emphasize supply factors. In an attempt to determine the amount of variation in hog prices that is due to changes in supply, hog prices were regressed on trend, seasonality factors, and average hog slaughter. The regression produced an R-squared value of 0.8610 which indicates that approximately 86% of the variation in hog prices during this sample period is due to trend, season, and variation in hog slaughters. Numerous combinations of the following data series were tested in trying to explain market hog prices: U. S. federally inspected hog slaughter, U. S. federally inspected sow slaughter, U. S. pork production, hog-corn ratio, USDA estimates of 14 state inventories of breeding hogs, market hogs, and total hogs. The best fit obtained for a 16 week forecast has an R-squared value of 0.8892. The model is given in Equation 3.

$$P_t = \beta_0 + \beta_1 t + \beta_2 \sin \frac{2\pi t}{S} + \beta_3 \cos \frac{2\pi t}{S} + \beta_4 P_{t-16} + \beta_5 HS_{t-16} + \beta_6 MHI_{t-24} + \beta_7 HCR_{t-52} + \beta_8 RSSHS + \beta_9 ARSS_{t-37} + \beta_{10} BHI_{t-30} + \text{Error} \quad (3)$$

The variables are defined as:

P_t = average weekly market hog price in dollars per hundred-weight at time t

t = 1, 2, ..., 522

S = 26 weeks

HS = 5 week moving average of U. S. federally inspected hog slaughter

MHI = USDA estimate of 14 state market hog inventory

HCR = hog-corn ratio in Omaha

RSSHS = ratio of 5 week moving average of U. S. federally inspected sow slaughter in week t-44 to HS_{t-28}

ARSS = 5 week moving average of residual sow slaughter. The residual sow slaughter is developed by regressing sow slaughter on trend and a 12 month seasonal component.

BHI = USDA estimate of 14 state breeding hog inventory

The results from the OLS regression and the correction for autocorrelation for Equation 3 are presented in Table IV. After the correction for first-degree autocorrelation was made the t-tests indicated that the estimates of the coefficients for the lags of hog prices, market hog inventory, hog-corn ratio, and the ratio of sow slaughter to hog slaughter were not significantly different from zero. Therefore, the equation was reestimated without these variables.

A format similar to Equation 3 was used to predict market hog prices 46 weeks in advance. It is presented in Equation 4.

$$P_t = \beta_0 + \beta_1 t + \beta_2 \sin \frac{2\pi t}{S} + \beta_3 \cos \frac{2\pi t}{S} + \beta_4 P_{t-46} + \beta_5 HCR_{t-52} + \beta_6 MHI_{t-46} + \beta_7 BHI_{t-46} + \beta_8 ARSS_{t-46} \qquad (4)$$

All variables have been previously defined.

The results from estimating this equation both with and without correction for autocorrelation are presented in Table V. Two variables, the lags of hog prices and market hog inventory, were dropped from the equation after making the correction for autocorrelation. The t-tests for these two variables indicated their coefficients were not significantly different from zero.

A causal predictor of feeder pig prices was not developed. Instead, the cyclical feeder pig price predictor is used whenever the causal price forecasting method is simulated.

The simulation model uses the prices predicted to make decisions about sow herd size and feeder pig sales and purchases. It should be

TABLE IV

TRACKING MARKET HOG PRICES (1970-1979) USING A CAUSAL MODEL AND 16 WEEK FORECAST

Parameter	Before Correcting for Autocorrelation		After Correcting for Autocorrelation	
	Estimate	t-test	Estimate	t-test
β_0	80.07	13.08	96.09	10.82
β_1	.0387	13.88	.0419	8.87
β_2	3.702	9.38	2.816	7.11
β_3	1.063	3.75	1.264	3.53
β_4	.1375	2.70		
β_5	-.0150	5.78	.0049	2.65
β_6	.4873	3.47		
β_7	.5253	7.05		
β_8	130.4	4.63		
β_9	.1510	6.97	.0734	2.67
β_{10}	-9.863	13.16	-7.897	5.78
R^2	0.8528		0.8892	

TABLE V

TRACKING MARKET HOG PRICES (1970-1979) USING A CAUSAL MODEL AND 46 WEEK FORECAST

Parameter	Before Correcting for Autocorrelation		After Correcting for Autocorrelation	
	Estimate	t-test	Estimate	t-test
β_0	83.69	17.20	66.47	4.72
β_1	.0408	14.54	.0389	4.36
β_2	2.3722	6.67	1.917	5.42
β_3	.0398	0.11	.6352	1.84
β_4	.0535	1.18		
β_5	.1939	2.55	.1958	2.50
β_6	.1332	1.29		
β_7	-9.055	14.15	-6.505	3.98
β_8	.2483	10.60	.0645	2.11
R^2	0.7780		0.8111	

noted that the causal and cyclical predictors have enhanced accuracy since both were developed using the same data series they are meant to predict. Due to the wide dispersion of livestock market information in the United States, the naive predictor and the futures market price predictor can easily be used by pork producers. Price forecasting methods like the causal predictor or the cyclical predictor require computer facilities. Therefore, they are much more restricted in their direct use by farmers; although, price forecasts can be disseminated. Since a perfect predictor of hog prices does not exist, the obstacles to its use are formidable indeed.

Farrow-to-Finish Systems

Two farrow-to-finish production systems, a pasture system and a confinement system, are simulated by the model. The pasture system required $19,492 (1979 dollars) initial investment in facilities and equipment and required 35 hours of labor per sow per year. Two sow groups, each with a maximum of 20 farrowing females, are farrowed twice annually. Since conception rates are less than 100%, more than 20 females must be bred in order to farrow 20 litters. The four farrowing periods permit production of 80 litters per year using only 20 farrowing units. The confinement system requires an initial investment of $154,622 with three groups of 30 sows being farrowed an average of 2-1/6 times annually. The confinement system requires 20 hours of labor per sow per year. Physical plans of the confinement and pasture farrow-to-finish production systems used in this study are discussed by Bloome et al. (1974) and Bloome et al. (1978), respectively.

Production Requirements

The production assumptions used when computing investment requirements and costs of production for the farrow-to-finish swine enterprises under the two production systems are summarized in Table VI. Compared with the confinement enterprise, the pasture farrow-to-finish enterprise is expected to have lower conception rates, smaller litter size, and lower feed efficiency. In addition, the pasture operation requires more hours of labor to produce each hog marketed. Should any feeder pigs be purchased, post-weaning death loss increases from 2% to 3% on all pigs in the feeding phase with the purchased pigs. The production coefficients used for these systems represent those of a good to above-average producer.

The production schedules for the two farrow-to-finish enterprises are shown in Table VII. The pasture system requires a longer production period than the confinement system. Two additional weeks are required in the breeding cycle--one week during breeding and one week during lactation. The rate of gain is also slower in the pasture system. Pigs are one week older when they reach 50 pounds and two weeks older at slaughter weight than their counterparts in the confinement system.

Detailed labor requirements for the two farrow-to-finish swine enterprises are presented in Table VIII. The pasture system requires almost twice as much labor per sow and litter (10 hours) as does the confinement system (5.07 hours). After the pigs are weaned the pasture system requires one hour of labor per pig to carry the pigs to slaughter weight as compared to .6 hours in the confinement system. The labor requirements presented do not include indirect time spend performing management functions such as planning, marketing, and recordkeeping.

TABLE VI

PRODUCTION COEFFICIENTS FOR A 90 SOW CONFINEMENT AND A 40 SOW PASTURE FARROW-TO-FINISH SWINE PRODUCTION SYSTEM

Item	Unit	Pasture System[a]	Confinement System[a]
Conception Rate			
Gilts	pct.	75.00	80.00
Sows	pct.	80.00	90.00
Pigs Weaned			
Gilts	no./ltr.	6.80	7.50
2nd litter sow	no./ltr.	7.50	8.00
3rd litter sow	no./ltr.	8.00	8.50
4th litter sow	no./ltr.	8.00	8.50
Litters/Sow	no./year	2.00	2.17
Death Loss[b]			
Raised pigs	pct.	2.00	2.00
Purchased pigs[c]	pct.	3.00	3.00
Feed Conversion	lbs. feed/lb. gain	4.00	3.80
Labor Requirements	hrs./year	35.00	20.00

[a]Figures are based on a sow unit.

[b]Post weaning.

[c]If feeder pigs are purchased post-weaning death loss increases from 2% to 3% on all pigs.

TABLE VII

PRODUCTION SCHEDULE FOR PASTURE AND CONFINEMENT FARROW-TO-FINISH SYSTEMS

Item	Pasture System (weeks)	Confinement System (weeks)
Length of Breeding Cycle	26	24
Time Until Pregnancy Testing	10	9
Length of Breeding & Gestation	20	19
Age of Pigs:		
when feeding begins	2	2
at weaning	6	5
at 50 pounds	11	10
at 230 pounds	27	25
Period of Pig's Life When:		
pigs are nursing	1-6	1-5
starter is fed	3-11	3-10
grower is fed	12-19	11-18
finisher is fed	20-27	19-25

TABLE VIII

LABOR REQUIREMENTS FOR 40 SOW PASTURE AND 90 SOW CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISES

Period	Pasture System		Confinement System	
	Time (weeks)	Labor Required (hours)	Time (weeks)	Labor Required (hours)
Sows:				
Breeding	4	0.15/female/week	3	0.08/female/week
Early Gestation	6	0.15/female/week	6	0.08/female/week
Late Gestation	10	0.15/female/week	10	0.08/female/week
Farrowing	6	1.16/female/week	5	0.71/female/week
Total	26	10.0/female/litter	24	5.07/female/litter
Pigs:				
Farrowing	6	included in sow labor	5	included in sow labor
Starting	5	0.05/pig/week	5	0.03/pig/week
Growing	8	0.05/pig/week	8	0.03/pig/week
Finishing	8	0.04/pig/week	7	0.03/pig/week
Total	27	1.0/pig	25	0.60/pig

Table IX presents the feed requirements used in modeling the pasture farrow-to-finish enterprise. Overall, the pasture system requires four pounds of feed for each pound of pork produced. The feed requirements for the 90 sow confinement farrow-to-finish swine enterprise are presented in Table X. The overall enterprise feed conversion ratio for the confinement system is 3.8 pounds of feed consumed per pound of pork produced. This is slightly better than the feed conversion rate for the pasture farrow-to-finish enterprise. The pasture system requires an additional 119 pounds of ration per litter for each sow. This is due to the longer breeding cycle in the pasture system. Market hogs produced in the pasture system consume 19 pounds more feed than do hogs in the confinement system.

Under both the pasture and confinement systems, any replacement gilts kept for breeding are fed 35 pounds of sow-boar ration per week. All boars are fed eight pounds of ration per day. The composition of rations being fed is the same for both systems.

Cost Data

One of the most common problems which arises in modeling historical situations is the development of accurate cost figures for the period being modeled. This is made even more difficult by the high rates of inflation which have occurred in recent years. In this study, three approaches were taken to derive cost values for inputs. Some costs are assumed to remain constant, historical values are used for some, and a point-deflating process is used for some. In using the latter technique, costs of inputs are calculated by obtaining estimates of their values in 1979. These values are then deflated to obtain estimates of January, 1970, values. These values, in turn, are inflated

TABLE IX

FEED REQUIREMENTS FOR 40 SOW PASTURE FARROW-TO-FINISH SWINE ENTERPRISE

Period	Time (weeks)	Ration	Percent Protein	Feed Consumed Per Animal Per Week (pounds)	Feed Consumed Per Animal Per Period (pounds)
Sows:					
Breeding	4	Sow-boar	14	35	140
Early Gestation	6	Sow-boar	14	35	210
Late Gestation	10	Sow-boar	14	35	350
Farrowing	6	Sow-boar	14	84	504
Total	26	---	--	--	1204
Pigs:					
Farrowing	6	Milk & Starter			
Starting	5	Starter	18	5.5	50
Growing	8	Grower	16	33	267
Finishing	8	Finishing	14	53	420
Total	27	---	--	--	737
Boars:					
Year	52	Sow-boar	14	56	2912

TABLE X

FEED REQUIREMENTS FOR 90 SOW CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISE

Period	Time (weeks)	Ration	Percent Protein	Feed Consumed Per Animal Per Week (pounds)	Feed Consumed Per Animal Per Period (pounds)
Sows:					
Breeding	3	Sow-boar	14	35	105
Early Gestation	6	Sow-boar	14	35	210
Late Gestation	10	Sow-boar	14	35	350
Farrowing	5	Sow-boar	14	84	420
Total	24	---	--	--	1085
Pigs:					
Farrowing	5	Milk & Starter			
Starting	5	Starter	18	7.5	60
Growing	8	Grower	16	32	256
Finishing	7	Finishing	14	57	402
Total	25	---	--	--	718
Boars:					
Year	52	Sow-boar	14	56	2912

weekly to obtain values over the entire simulation period. The source of the inflation indices is the 1980 annual summary of Agricultural Prices.

The highest inflation rate used is for utilities. Utilities are inflated at an annual rate of 10.4%. Fuel, lubrication, and repair on machinery and equipment are inflated at a rate which is only slightly lower--10.3%. Wages increase at an annual rate of 8.2%. The inflation rate for interest on borrowed capital is the lowest--3.4%. Costs associated with feed storage, veterinary and medicine, straw, hedging costs, marketing fees, the non-feed costs of owning boars, and transportation expenses are inflated at an annual rate of 7.6%.

Cost figures for swine enterprises in January, 1979 form the base for the point-deflating technique. Costs for utilities for the pasture system in 1979 are estimated as eight dollars for a sow and litter up to two weeks of age. After pigs are two weeks old, they are charged two cents per pig per week. For the confinement system, a charge for utilities of $9.78 is made per sow and litter. After the pigs reach two weeks, an additional 4.17 cents per week is charged for each pig. A charge is made for fuel, lubrication, and repair on machinery. For the pasture system, this expense is $9.75 per sow and litter. After the pigs reach two weeks of age, each pig is charged 2.38 cents per week. Fuel, lubricant, and repair costs for the confinement system are slightly higher. For a sow and litter, a charge of $11.30 is made. An additional 3.75 cents per week is charged for pigs over two weeks of age. The point-deflating technique is used on 1979 utility and fuel, lubricant, and repair expenses to obtain cost estimates for the entire simulation period. The expense values for the start and the end of the simulation period are presented in Table XI.

TABLE XI

STARTING AND ENDING COST DATA AND ANNUAL INFLATION RATES FOR PRODUCTION AND MARKETING EXPENSES

Item	System[a]	January 1970 Value ($)	December 1979 Value ($)	Annual Inflation Rate[b] (%)
Utilities/litter	P	3.86	10.39	10.4
Utilities/litter	C	4.72	12.70	10.4
Utilities/pig/week	P	.0096	.026	10.4
Utilities/pig/week	C	.02	.054	10.4
Fuel, lube, repair/litter	P	4.03	10.72	10.3
Fuel, lube, repair/litter	C	4.67	12.42	10.3
Fuel, lube, repair/pig/week	P	.01	.026	10.3
Fuel, lube, repair/pig/week	C	.015	.041	10.3
Hedging cost/contract	B	30.00	62.18	7.6
Boar cost/week	P	1.11	2.30	7.6
Boar cost/week	C	1.42	2.94	7.6
Gilt premium/head	B	35.00	72.55	7.6
Vet-med/head sold	P	.75	1.55	7.6
Vet-med/head sold	C	.50	1.04	7.6
Haul & market/head sold	B	.87	1.81	7.6
Straw/head sold	P	.25	.53	7.6
Interest/dollar borrowed	B	.078	.109	3.4
Labor/hour	B	1.75	3.85	8.2
Feed storage/cwt/week	B	.0045	.0093	7.6

[a]P denotes Pasture system; C denotes Confinement system; B denotes Both systems.

[b]The simulation model calculates inflation on a weekly basis.

The cost of hedging a futures contract was set at $30 in January, 1970, and inflated by 7.6% each year. Boar expenses, other than feed, are treated by the model as fixed rather than variable costs. The pasture system requires four boars and the confinement system requires five. When the option of expanding sow numbers beyond the design capacity level is available (Strategies E and F), each system will require two additional boars. Beginning in 1970, boar costs are charged to the confinement system at the rate of $1.42 per boar per week. This cost is inflated by 0.14% each week. The initial cost to the pasture system is $1.11 per boar per week. This cost is also inflated by 0.14% weekly. Replacement gilts, when purchased, are assumed to weigh 250 pounds and cost a varying amount over the current value of 230 pound market hogs. This variable charge is set at $35 for the first week of January, 1970, and is inflated by 0.14% each week for the remainder of the simulation. This results in a premium of $72.55 ($35.00 \times 1.0014^{521}$) above the value of market hogs being paid for replacement gilts in the last week of the 522 week simulation period.

Several expenses are calculated on the basis of sales. The 1970 charge for veterinary and medicine expenses is 75 cents per head marketed by the pasture system and 50 cents per head for the confinement system. Hauling and marketing cost in January, 1970, is estimated at 87 cents per head sold regardless of the system being modeled. An initial charge of 25 cents per head marketed by the pasture system is made for straw. Only the pasture system uses straw.

All investment capital and any operating capital required by the swine enterprise is assumed to be borrowed at an interest rate consistent with what Production Credit Associations were charging during the 1970s. According to the USDA's Crop Reporting Board (1980), PCAs were charging an annual rate of interest of 7.8% on their loans in 1969. By late 1979, the average rate for loans had increased to 10.9%. Rather than tracking the exact movements of interest rates between these two dates, a linear trend is assumed. This results in interest rates inflating by 0.064% each week. Should the enterprise being simulated generate sufficient revenue to retire all debt, surplus capital is assumed to be placed in an interest bearing account. A 5% annual rate of return on surplus capital is received. This rate of return is not varied over the simulation period.

Labor costs are set at $1.75 per hour for the first week and are inflated by 0.15% each week. This yields a wage of $3.85 per hour for labor during week 522. No charge is made for management or for income taxes. However, a nominal charge of one percent of the depreciated value of the non-livestock inventory is made for property taxes and insurance.

No charge is made for land for any of the systems. It was decided that an equitable and widely applicable land rental charge was difficult, if not impossible to obtain. The pasture farrow-to-finish enterprise requires about ten acres of land for direct use. The confinement enterprise requires about five acres for direct use. This does not include acreage needed for waste disposal and to provide insulation against odor pollution problems.

The largest single expense in raising hogs is feed. Williams and Plain (1978) indicate that feed accounts for approximately 65-75% of the cost of producing market hogs. Because of its major influence on total costs plus its highly variable nature, feed costs are estimated from historical data for this study.

Monthly average prices for hog feed and hog concentrate published in Agricultural Prices (1970-1980) were selected to estimate feed costs. Since January, 1977 (week 367), the USDA's Crop Reporting Board has published monthly average Oklahoma prices for 14-18% hog feed and 38-42% hog concentrate. Prior to 1977 the USDA reported only quarterly prices for Oklahoma. As a result, it was necessary to use U. S. monthly average prices and make an adjustment to obtain an estimate for Oklahoma. After comparing the quarterly Oklahoma prices with the monthly U. S. prices, a decision was made to use 95% of the U. S. monthly average price as a substitute for Oklahoma prices.

Prices are required for four types of hog feed--starter, grower, finisher, and sow-boar ration. The cost of grower ration is set equal to the Oklahoma price for 14-18% hog feed. Finishing ration is priced at 94% of the cost of grower ration. Sow-boar ration is set equal to 50% of the price of finishing ration plus 19% of the price of 100 pounds of hog concentrate. Starter ration is valued at 150% of sow-boar ration price.

A feed storage charge is assessed from the date of purchase until the feed is fed. This charge is set at 0.45 cents per week per hundredweight of feed in January, 1970. The storage cost is inflated by 0.14% each week. This produces a weekly charge of 0.93 cents per hundredweight for the final week of 1979.

Expansion Beyond Capacity

Additional facilities are required to expand the breeding herd beyond the design capacity level. If the sow herd is increased above design capacity in either the pasture or confinement system, additional sows are farrowed in individual wooden houses. If the option of expanding the breeding herd above design capacity is included, then the additional facilities required are purchased the first week of the simulation and are maintained throughout the simulation period, whether or not they are actually used. Production coefficients for extra farrowings are the same for both systems.

A loss in production efficiency occurs whenever hog numbers exceed the design capacity. Factors which are affected by the loss in efficiency are conception rates, litter size, feed efficiency, labor requirements, death loss, utilities, fuel, lubricant, and repair expenses. When expansion in the breeding herd occurs, extra gilts must be added. It is assumed that these extra gilts farrow in the overflow facilities. The conception rate on these extra gilts is set at 70% and litter size is 5.8 pigs per litter. Pigs from these gilts are fed 70 pounds of starter ration each, prior to reaching 50 pounds. Fifteen hours of labor per sow and litter up to weaning are required for these extra farrowings. For gilts in the overflow facilities, 1970 utilities charges are $4.25 per litter. Fuel, lubricant, and repair charges are $8.06 per litter.

Additional pigs in the finishing phase are handled by crowding more pigs into the same facilities. No additional finishing facilities are purchased. The maximum number of pigs allowed at any one point is 382 in the confinement farrow-to-finish enterprise and 320 in the pasture enterprise. When the number of pigs in the growing and finishing facilities exceeds the design capacity, a drop in feed efficiency occurs. The additional feed required per pig is equal to a fraction of the percentage by which capacity is exceeded. This fraction is one-tenth for the pasture system and one-fifth for the confinement system. For example, if the number of pigs in a pen is 20% above the design capacity level of that pen, then those pigs would require 2% (one-tenth of 20%) more feed if they are in the pasture system, and 4% (one-fifth of 20%) more feed if they are in the confinement system, than would pigs in a pen which is not above design capacity.

Facilities and Costs

Table XII presents a detailed listing and description of the facilities, machinery, and equipment that are required for the 40 sow pasture farrow-to-finish enterprise. Initial investment in facilities, machinery, and equipment, excluding land and livestock, is $487 per sow unit. Prices presented are 1979 values.

The additional investment requirements for the expanded version of the pasture system is presented in Table XIII. These facilities are the minimum additions which are considered necessary to allow for expansion by 10 sows per farrowing. The expanded system is not intended to handle 60 sows and their pigs as efficiently as the smaller system can accommodate 40 sows. Rather, it is designed to allow for temporary expansion in the breeding herd at times when price forecasts indicate additional profits can be made. No additions are made to growing and finishing facilities. Additional pigs produced by the extra sows are crowded into the same facilities available to the smaller 40 sow pasture system. As a result of this overcrowding, all pigs being fed suffer a loss in efficiency.

The facilities, machinery, and equipment investment requirements for the 90 sow confinement farrow-to-finish system are presented in Table XIV. The confinement system requires an initial investment, not

TABLE XII

FACILITIES, MACHINERY, AND EQUIPMENT INVESTMENT FOR A 40 SOW PASTURE FARROW-TO-FINISH SYSTEM

Item	Size and Description	Units Needed (no.)	Life (years)	Cost/Unit[a] (dollars)	Total Investment[a] (dollars)
Gilt and Boar Facilities:					
Gilt shelter	100 sq. ft.	1	15	234	234
Boar shelter	40 sq. ft.	1	15	117	117
Pen	woven wire	1	15	909	909
Waterers	1 hole	3	8	11	33
Fogger	plastic pipe	1	8	50	50
Subtotal					1343
Gestation Facilities:					
Pens	375' x 375'	2	15	458	916
Sow shelters	200 sq. ft.	4	15	350	1400
Waterers	1 hole	4	8	11	44
Fogger	plastic pipe	1	8	100	100
Subtotal					2460
Farrowing Facilities:					
Pen	375' x 375'	1	15	1092	1092
Farrowing huts	lumber	20	8	138	2760
Waterers	1 hole	2	8	11	22
Sow feeder	60 bushels	1	8	180	180
Creep feeders	creep	2	8	126	252
Fogger	plastic pipe	1	8	50	50
Subtotal					4356

TABLE XII (Continued)

Item	Size and Description	Units Needed (no.)	Life (years)	Cost/Unit[a] (dollars)	Total Investment[a] (dollars)
Finishing Facilities:					
Pens	100' x 100'	2	15	581	1162
Shelters	300 sq. ft.	4	15	525	2100
Waterers	1 hole	8	8	11	88
Feeders	60 bushels	6	8	267	1602
Fogger	plastic pipe	1	8	100	100
Subtotal					5052
Supportive Facilities, Machinery and Equipment					
Loading chute	wood	1	8	215	215
Pickup[b]		1	8	3330	3330
Stock trailer		1	10	1636	1636
Water delivery system		1	15	1100	1100
					6291
Total Facilities, Machinery, and Equipment					19,492

[a]1979 dollars.

[b]Fifty percent of the original $6,660 investment is allocated to the swine production enterprise.

TABLE XIII

ADDITIONAL FACILITIES, MACHINERY, AND EQUIPMENT INVESTMENT NEEDED TO ALLOW 40 SOW PASTURE FARROW-TO-FINISH ENTERPRISE TO EXPAND TO 60 SOWS

Item	Size and Description	Units Needed (no.)	Life (years)	Cost/Unit[a] (dollars)	Total Investment[a] (dollars)
Gilt and Boar Facilities:					
Waterers	1 hole	1	8	11	11
Gestations Facilities:					
Pens	375' x 375'	1	15	458	458
Sow shelters	200 sq. ft.	2	15	350	700
Waterers	1 hole	2	8	11	22
Farrowing Facilities					
Farrowing huts	lumber	10	8	138	1380
Waterers	1 hole	1	8	11	11
Creep feeders	creep	1	8	126	126
Total Facilities					2708

[a]1979 dollars.

TABLE XIV

FACILITIES, MACHINERY, AND EQUIPMENT INVESTMENT REQUIREMENTS FOR A 90 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Item	Life (years)	Investment[a] (dollars)
Gestation and Breeding:		
Facilities	20	22,982
Equipment	10	2,880
Subtotal		25,862
Farrowing-Growing:		
Facilities	20	49,709
Equipment	10	15,055
Subtotal		64,764
Finishing:		
Facilities	20	45,965
Equipment	10	5,760
Subtotal		51,725
Supportive Facilities, Machinery, and Equipment:		
Lagoon	20	2,727
Water delivery system	20	2,182
Generator	20	1,636
L. P. supply	20	545
Loading chute	8	215
Pickup[b]	8	3,330
Stock trailer	10	1,636
Subtotal		12,271
Total Facilities, Machinery, and Equipment		154,622

[a]1979 dollars.

[b]Fifty percent of the original $6,660 investment is allocated to the swine production enterprise.

including land and livestock, of $1,718 per sow unit. The additional facilities needed to allow for the expansion of each of the three sow groups in the confinement system by ten sows are given in Table XV. The nature of the facilities used by the confinement system makes expansion with the same kind of facilities a very expensive option. As a result, expansion is achieved by using the type of facilities utilized by the pasture system. No additions are made to growing or finishing facilities. Additional pigs produced are crowded into the same facilities with pigs from the initial farrowings.

Both systems have some equipment with eight year life expectancies. New equipment is purchased to replace these items at the start of the ninth year of the simulation period.

Swine Enterprise Simulation Model

The economics of adaptive planning under price uncertainty is analyzed using a deterministic computer model to simulate selected production and marketing strategies for the two farrow-to-finish swine enterprises over a ten year period beginning in January, 1970. By simulating a historical period, the advantage of hindsight is available for evaluating performance in light of actual rather than hypothetical price variations. The analysis utilizes a profit-optimizing dynamic simulation model developed specifically for this study. The model allows weekly management decisions and reports levels of production and cash flows which result from the decisions. An iterative procedure is used to equate expected marginal cost and expected marginal revenue within the constraints placed on output levels by management strategies. When a perfect price predictor is simulated expected values are equal to actual values and profits are maximized.

TABLE XV

ADDITIONAL FACILITIES, MACHINERY, AND EQUIPMENT INVESTMENT NEEDED TO ALLOW 90 SOW CONFINEMENT FARROW-TO-FINISH ENTERPRISE TO EXPAND TO 120 SOWS

Item	Size and Description	Units Needed (no.)	Life (years)	Cost/Unit[a] (dollars)	Total Investment[a] (dollars)
Gilt and Boar Facilities:					
Gilt shelter	50 sq. ft.	1	15	117	117
Boar shelter	20 sq. ft.	1	15	59	59
Pen	woven wire	1	15	454	454
Waterer	2 hole	1	8	17	17
Fogger	plastic pipe	1	8	25	25
Gestation Facilities:					
Pen	375' x 375'	1	15	458	458
Sow shelters	200 sq. ft.	2	15	350	700
Waterers	1 hole	2	8	11	22
Fogger	plastic pipe	1	8	50	50
Farrowing Facilities:					
Pen	190' x 190'	1	15	546	546
Farrowing huts	lumber	10	8	138	1380
Waterer	1 hole	1	8	11	11
Sow feeder	30 bushel	1	8	90	90
Creep feeder	creep	1	8	126	126
Fogger	plastic pipe	1	8	25	25
Total Factilities					4080

[a]1979 dollars.

A limited planning horizon is used in making management decisions. Although sows can be retained for a maximum of four litters, only the economics associated with the next litter is incorporated when making culling or replacement decisions.

Assumptions

The model assumes an unlimited line of credit is available and that any surplus capital is deposited in an interest bearing account. All livestock sold are assumed to bring the average market price for the week in which they are marketed. Feed prices used are equal to the average price for the month in which the feed is purchased. Labor is assumed to be a totally variable input, and straight line depreciation is used on depreciable assets.

Numerous assumptions are made about the operation of the swine enterprises. All production and marketing decisions are made on the first day of the week and are irreversible. Feed is purchased when production decisions are made and stored until needed. A strict production schedule is maintained. If sows are eliminated due to unfavorable prices, they cannot be replaced until the proper sequence in the breeding schedule returns. Pigs are sold when they weigh either 50 or 230 pounds. In order to simplify the calculations in the model, it was assumed that all hogs are sold or purchased at a fixed weight as given in Table XVI. The economics associated with selling pigs for breeding or show stock is not considered. In no case are sales advanced or delayed in hope of obtaining more favorable prices. Feeder pigs can only be purchased at the point in the feeding cycle when raised pigs weigh 50 pounds. A complete complement of boars is always maintained. This is done because of the large differential between acquisition cost and salvage value. It is assumed that replacement boars cost $300 when purchased and are kept for one year. Sows are kept a maximum of four litters. All production coefficients are known. The only uncertainties are prices and costs. The operator is risk indifferent.

TABLE XVI

WEIGHTS USED IN COMPUTING COSTS AND RETURNS

Animal	Weight (pounds)
Feeder Pigs	50
Market Hogs	230
Nonbreeder Gilts	325
Cull Sows	400
Cull Boars	425
Replacement Gilts	250
Replacement Boars	260

Several assumptions are made about the swine enterprises. Constant technology is assumed. Production coefficients are held constant as long as hog numbers are at, or below, capacity. Weather is not a factor in production. The swine enterprises are assumed to be producing at the point of minimum average total cost when at design capacity. Deviation from capacity results in increased average costs per unit of output. Reducing output below design capacity increases average fixed costs per unit. Increasing output above capacity results in higher average variable costs per unit and lower average fixed costs.

It is assumed the increases in average variable costs per unit are greater than reductions in fixed costs. Uniform breeding and growth patterns are assumed. All females within a breeding group farrow at the same time and their pigs reach market weight at the same age.

These assumptions result in cost curves which are different than the ones given in Figure 4. The short run cost curves for the sow breeding portion of the farrow-to-finish enterprise are given in Figure 12. The marginal cost curve has flat segments and increases in stair-step fashion. This is caused by the assumptions of constant cost and production coefficients for each class of female (as long as the sow herd is below design capacity) and different production parameters for different classes of females. The marginal cost curve is highest from design capacity to the maximum capacity allowed. This results from smaller litter sizes and higher production costs associated with sows in the excess capacity facilities.

If an enterprise is operating at design capacity with a sow herd composed of sows with a variety of ages, it can increase its efficiency and lower its marginal cost by eliminating gilts since they have smaller litters. The marginal cost curve declines whenever a younger-than-average female is eliminated from the breeding herd. As is always the case, the average variable cost curve reflects changes in marginal cost as sow numbers increase. The average fixed cost curve is a rectangular hyperbola. The average total cost curve is the verticle summation of the average variable cost curve and the average fixed cost curve.

Control Variables

A flow chart of the simulation model is shown in Figure 13. The

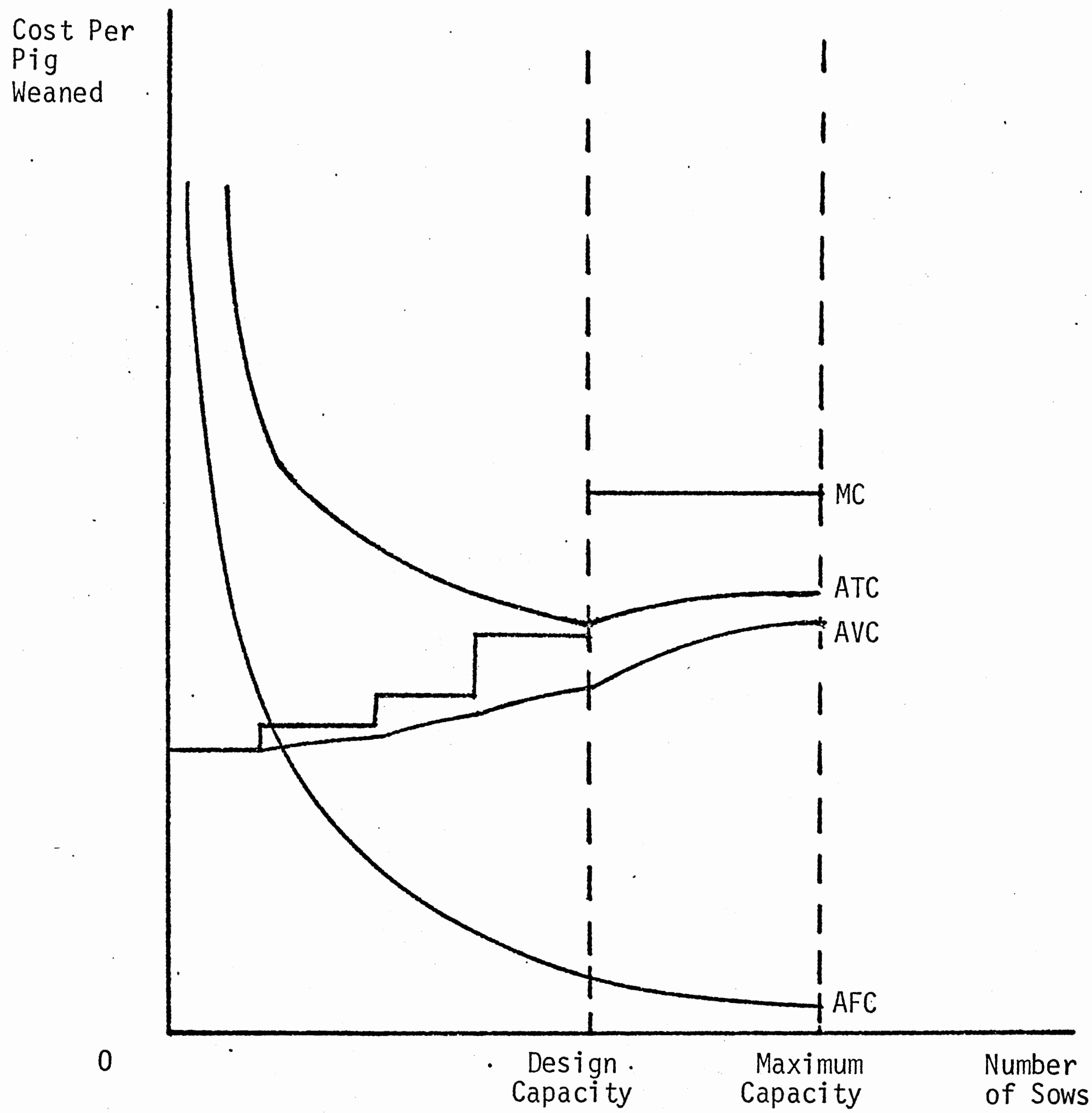

Figure 12. Short-Run Cost Curves for Sow Herd

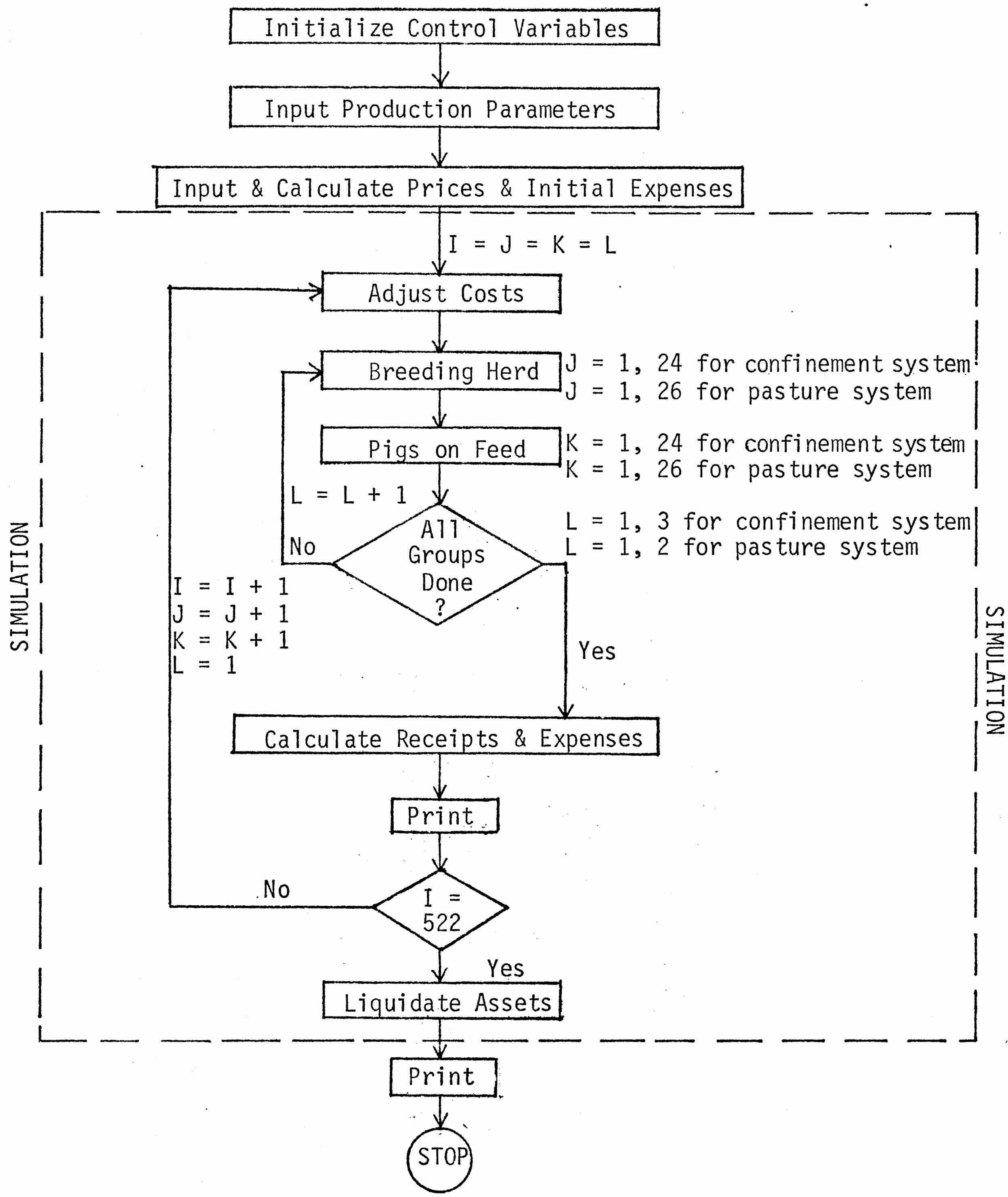

Figure 13. Flow Chart of Farrow-to-Finish Simulation Model

model operates in the following general manner. First, the model is initialized. In this process values are assigned to the control variables. These variables identify to the model the type of simulation which is to be performed. The model has 14 control variables. The variables are presented in Table XVII.

The control variable, SYSTEM, specifies to the model which swine production system will be simulated. Six acceptable values exist for SYSTEM. They represent the three types of swine enterprises--farrow-to-finish, feeder pig production, and finishing purchased pigs--in either a pasture or a confinement system. Only the pasture and the confinement farrow-to-finish enterprises are simulated in this study.

MODEL determines what price prediction method will be used. There are six possible values for MODEL, one for each of the five price prediction methods which can be simulated (perfect, naive, futures, causal and cyclical) and a sixth value for no price prediction (the nonflexible strategy).

MSOWNO controls the size of the sow herd in the farrow-to-finish and feeder pig production simulations. MSOWNO has four possible values. To simulate management strategies A and B, the sow herd is held at design capacity. The sow herd is allowed to vary between zero and capacity for strategies C and D. For Strategy E, sow numbers vary between design capacity and a higher maximum allowable level (in this study, ten additional sows per breeding group). Strategy F allows the greatest variation in herd size. Sow numbers can vary from zero to the maximum level.

MSOWSL identifies the criterion used in making adjustments in the size of the sow herd. Adjustments in sow numbers can be made on the basis of forecasts of future feeder pig prices, or future market hog

TABLE XVII

SIMULATION MODEL CONTROL VARIABLES AND THEIR MEANINGS

Control Variable	Number of Possible Values	Production and Simulation Factors Controlled
SYSTEM	6	swine system and enterprise
MODEL	6	price prediction method
MSOWNO	4	sow herd size
MSOWSL	3	sow replacement criteria
MPIGSL	2	feeder pig sales option
PIGBUY	2	feeder pig purchase option
EXPIG	2	maximum number of pigs
MHEDGE	7	time of hedging and contract size
MBUYHG	2	selective hedge
PREBUY	2	timing of feed purchases
MRANL	2	random litter size
MRAND	2	random death loss
IFIRST	---	first week of simulation period
ILAST	---	last week of simulation period

prices, or a combination of feeder pig and market hog price forecasts. If a feeder pig production enterprise is modeled, sow numbers are a function of anticipated prices for feeder pigs. If the option of marketing feeder pigs is not available, then the sow herd size decision is made on the basis of expected market hog prices. As a general rule, if both feeder pig sales and market hog sales are allowed, then the decision on sow numbers is dependent upon price forecasts for both feeder pigs and market hogs. An exception is made in the cases where the futures market or the causal predictor is used for the price forecast. Since there is no futures market in feeder pigs, the decision must be based solely upon the futures market price for market hogs. A causal predictor for feeder pig prices was not developed. Instead, the feeder pig price predictions from the cyclical model are used whenever the causal model's forecasts for feeder pig prices are needed.

The number and disposition of the non-breeding stock is controlled by three variables--MPIGSL, PIGBUY, and EXPIG. MPIGSL determines whether or not the sale of feeder pigs is allowed. PIGBUY controls whether feeder pig purchases are allowed. EXPIG specifies whether the number of pigs may exceed the initial design capacity of the system.

Hedging strategy is controlled by the variable MHEDGE. A hedge can either be placed when the breeding decision is made or when the pigs reach 50 pounds. Since the size of a live hog futures contract (30,000 pounds) is not the same as the production of the swine system being simulated, a manager is faced with two options. He can hedge part of the pigs and speculate on what price will be received for the remaining pigs, or all of the pigs can be hedged. The latter choice necessitates the purchasing of futures contracts for more hogs than are owned. As a result, the manager will be speculating in the futures market for part of a contract. A third option is also made available. This is the option of buying a contract for the exact number of hogs owned. Although this is not practical in the futures market, it could be useful in simulating forward contracting. Neither the second nor third option is used in this study. The final hedging strategy controlled by MHEDGE is one in which no hogs are hedged. Unhedged pigs are sold at the prevailing market price.

The remaining six control variables are not varied for this study. MBUYHG is a control variable which allows a selective hedge to be placed. It simulates a hedge being placed only when feeder pigs are purchased by the system. No selective hedges are simulated.

PREBUY is a binary variable that controls whether feed is purchased in advance and stored or purchased the week it is fed. In this study, feed is always purchased in advance and stored until fed.

MRANL and MRAND are control variables which determine whether litter size and post-weaning death loss, respectively, are constant or random. Both are held constant in this study.

The final two control variables, IFIRST and ILAST, designate the first week and last week of the simulation period. For this study, IFIRST and ILAST are set at 1 and 522, respectively.

Production Parameters

After initialization of the control variables the model inputs the production parameters for the system which is to be modeled. These values identify the technical characteristics of the swine production system. Values include such things as labor and feed requirements, conception rates, litter sizes, death loss, and maximum sow numbers.

The model can simulate a wide range of swine production systems under varying levels of efficiency by altering the production parameters.

Price Data

The next step is for the model to input historical price data and calculate expected hog prices. The prices calculated are a function of the price prediction method being modeled. The model also calculates the initial investment expenses for buildings, machinery, equipment. breeding stock, and feed. All money necessary to make these initial purchases is borrowed at the beginning of the simulation period.

Simulation

After all data has been inputted and initial values have been calculated, the model begins the simulation process. There are four general indicators of the model's progress in simulating a farrow-to-finish swine enterprise--I, J, K, and L. I represents the week number. Week numbers go from 1 to 522, or from the first week of Janaury, 1970, to the end of December, 1979. The second indicator, J, is used to track the breeding cycle. The breeding cycle lasts for 24 weeks in the confinement system and 26 weeks in the pasture system. The progress of the feeding cycle is represented by K. The feeding cycle for each system is the same length as the breeding cycle for that system. The fourth indicator, L, identifies which of the different breeding and feeding groups is being modeled. Sows and their pigs in the confinement system are divided into three separate groups. Breeding is spaced so that farrowings occur at eight week intervals. Hogs in the pasture system are divided into two groups. The groups alternately farrow at 13 week intervals.

The model begins each week by reestimating production costs. It then proceeds to analyze the breeding herd and the pigs on feed. Hogs are analyzed according to the breeding and feeding groups to which they belong. After all groups have been analyzed receipts, expenses, and an accumulated total of cash flow and net revenue are calculated. Receipts are derived from the sale of livestock. In addition to the investment in buildings and equipment, expenses include livestock, feed, feed storage, labor, utilities, veterinary and medicine, hauling and marketing, fuel, lubricants, repair, insurance, interest, and property taxes. Costs are based on historical data. Interest payments provide a compounding and discounting effect and yield a final value for accumulated net returns in 1980 dollars. This financial data is printed along with the number of animals sold, feed and livestock inventories, and farrowings.

After the above information is printed, all hogs are advanced one week in age and the simulation proceeds to the next week. This process continues until the last week of the simulation period is reached, at which time assets are liquidated. All buildings, equipment, livestock, and feed on hand at the end of the simulation period are sold before calculating the final accumulated returns. Buildings and equipment are liquidated at book value. Livestock and feed are sold at market value. Assets are liquidated to account for differences in the value of ending inventories.

A chart depicting the flow of animals within a farrow-to-finish enterprise and the sequence of decisions modeled is shown in Figure 14. Old sows are culled, new gilts are added, and breeding begins during the first week of the breeding cycle. Initially, the model must decide

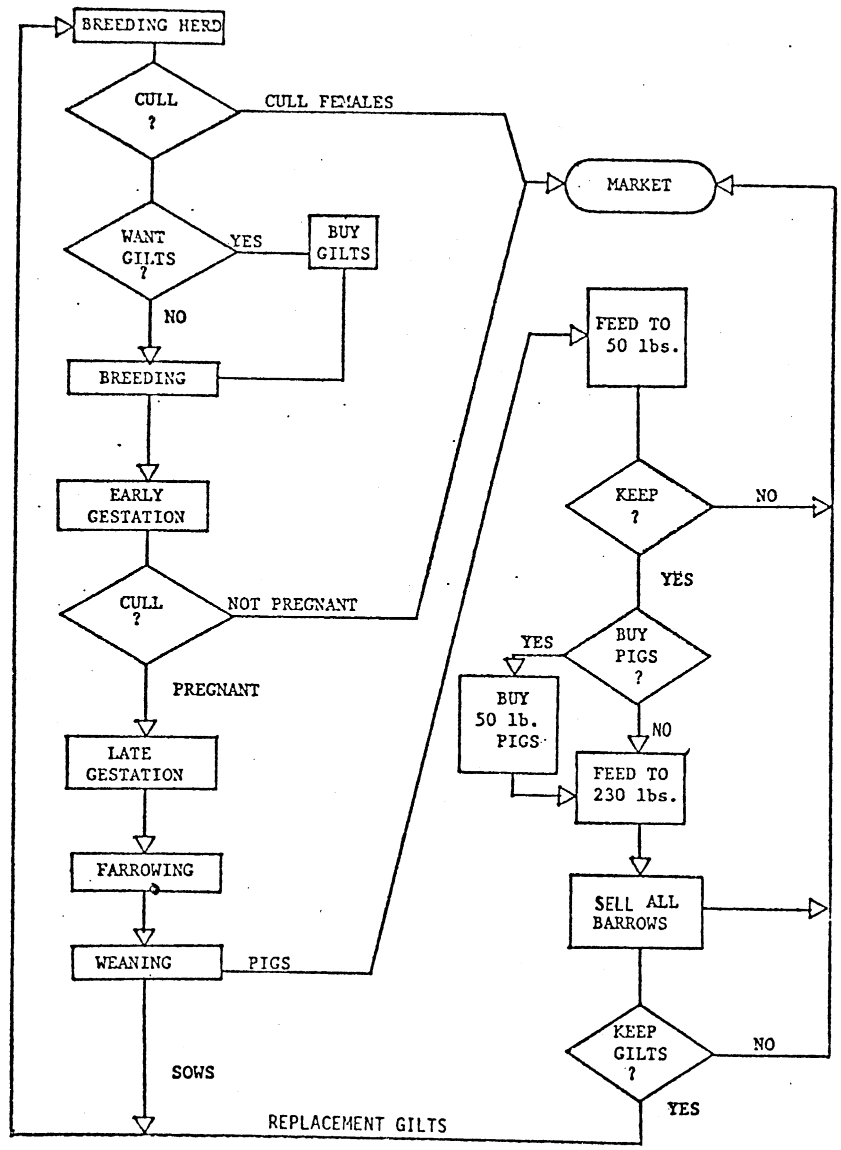

Figure 14. Movement of Swine and Decision Points Within Farrow-to-Finish Swine Model

if it appears profitable to breed and farrow gilts and/or sows. The answer to this question is based on the expected level of variable costs and hog prices. If the answer is yes, the females in the breeding herd are bred. Replacements are selected from raised market gilts if they are available. If not, replacement gilts are purchased. If the answer is negative, then a reduction in the breeding herd occurs.

Females are classified according to the number of litters which they have farrowed. Conception rates and litter size vary among classes of females. Females are culled from the breeding herd after having four litters or if the expected net present value from breeding and farrowing the female is less than her current market value. Future receipts and expenses are discounted at the cost of capital. Replacement gilts are purchased when needed, provided their expected net present value exceeds acquisition costs. An iterative procedure is used with each class of females examined separately. Due to differences in conception rates and litter sizes between sows and gilts, there may be times when it is profitable to breed and farrow sows but not profitable to add replacement gilts to the herd, or it may be profitable to add raised replacement gilts but not profitable to buy replacement gilts. When prices are favorable, sufficient females are bred to allow for culling of open females and still be able to fill the farrowing facilities. Pregnancy testing and the culling of unsettled females occur during the 10th and 11th weeks. Farrowing occurs during the 19th and 20th weeks.

Pigs are started on feed at two weeks of age. They are weaned at five weeks of age in the confinement system and when six weeks old in the pasture system. After weaning, sows are returned to the breeding herd and the pigs are moved to the feeding facilities. When the pigs reach 50 pounds a decision is made whether to sell the pigs as feeders or to feed them to 230 pounds. The pigs will be kept to slaughter weight if the expected discounted returns from continued feeding exceeds net receipts realized by marketing feeder pigs.

Another choice which the operator may face is the option of purchasing additional pigs to feed simultaneously. Death loss is increased if purchased feeder pigs are added to the herd. In addition, the feed conversion rate declines if the number of pigs in the feeding facility exceeds the design capacity. After reaching market weight, gilts needed for the breeding herd are saved and the remainder of the market hogs are sold.

CHAPTER IV

RESULTS

The simulation model was used to determine the production responses which result from using six management strategies in combination with five price prediction methods for both a pasture and a confinement farrow-to-finish swine enterprise. Sixty-two variations were simulated. The results are presented in this chapter. The chapter is divided into three sections. The first presents accumulated returns from the simulations and discusses the relative profitability of using each price prediction method. The second section presents four additional measures of performance and analyzes how each relates to returns, management strategies, and price prediction methods. The final section examines the six management strategies with respect to production, marketing, and returns.

Net Returns

The accumulated returns for the selected management strategies and price prediction methods for the pasture and confinement systems over the ten year simulation period are shown in Tables XVIII and XIX, respectively. Annual net cash flows are presented in the Appendix.

The simulation model indicates a positive accumulated total return to land, risk, and management for all strategies simulated using the confinement system. Five of the returns for the pasture system are less

TABLE XVIII

ACCUMULATED RETURNS TO LAND, RISK, AND MANAGEMENT FROM 1970 THROUGH 1979 FOR A PASTURE FARROW-TO-FINISH SWINE ENTERPRISE USING SELECTED PRODUCTION STRATEGIES (1980 DOLLARS)

No Flexibility Constant Full Capacity	(A) 44,515				
	Type of Flexibility				
Price Prediction Method	(B) Optional Feeder Pig Sales	(C) Variable Sow Numbers (0 to Capacity)	(D) Both B and C	(E) Optional Feeder Pig Sales & Variable Sow Numbers (Capacity to Capacity + 10)	(F) Optional Feeder Pig Sales & Purchases & Variable Sow Numbers (0 to Capacity + 10)
Naive	17,883	5,215	3,759	-11,695	-17,159
Futures Market	30,218	13,130	17,203	16,183	-11,824
Futures & Hedging	29,376	-21,505	9,369	14,988	-13,007
Causal	54,355	48,806	52,681	48,381	69,462
Cyclical	60,880	53,448	64,076	63,238	97,098
Perfect	63,940	67,624	76,862	71,153	110,603

TABLE XIX

ACCUMULATED RETURNS TO LAND, RISK, AND MANAGEMENT FROM 1970 THROUGH 1979 FOR A CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISE USING SELECTED PRODUCTION STRATEGIES (1980 DOLLARS)

No Flexibility Constant Full Capacity	(A) 177,919				
	Type of Flexibility				
Price Prediction Method	(B) Optional Feeder Pig Sales	(C) Variable Sow Numbers (0 to Capacity)	(D) Both B and C	(E) Optional Feeder Pig Sales & Variable Sow Numbers (Capacity to Capacity + 10)	(F) Optional Feeder Pig Sales & Purchases & Variable Sow Numbers (0 to Capacity + 10)
Naive	151,523	130,132	116,885	131,667	103,802
Futures Market	145,702	110,888	101,249	142,774	70,658
Futures & Hedging	139,009	30,127	87,320	136,000	65,859
Causal	213,540	177,227	209,674	226,080	223,760
Cyclical	220,680	183,840	218,075	240,517	262,131
Perfect	242,701	202,133	243,432	279,039	310,125

than zero. The returns to Strategy F (feeder pig sales and purchases and sow numbers variable from zero to capacity plus ten) using the naive, futures market, and futures with hedging price prediction methods are negative. In addition, Strategy E (feeder pig sales and sows variable from capacity to capacity plus ten) using the naive predictor and Strategy C (feeder pig sales and sow numbers variable from zero to capacity) using hedging fail to produce a positive return.

The returns to the confinement system are greater than to the pasture system for all management strategies regardless of the price forecast method used. The higher returns associated with the confinement system are due largely to a greater number of sows and more frequent farrowings. However, even on a per-litter-farrowed basis, the confinement system shows greater profitability than does the pasture system. Using the nonflexible (Strategy A) strategy, the confinement system shows a net return of $94 per farrowing as compared to $57 for the pasture system. However, when the rate of return on investment is calculated the relationship is reversed. The annual rate of return on investment (excluding land) for the pasture system under the nonflexible strategy is 17% while the rate of return to the confinement system using the nonflexible strategy is 9.2%.

Perfect Predictor

The perfect predictor simulates perfect knowledge of future hog prices. It bases management decisions on the actual market hog prices which occurred during the 1970s. Compared to the nonflexible, full capacity strategies, the management strategies using the perfect price predictor generate higher net returns for both the pasture and confinement systems. As expected, production and marketing flexibility is a definite asset when a perfect predictor is simulated. The greater the flexibility, the greater the returns. The difference in returns to the confinement system between the strategy of allowing optional feeder pig sales ($242,701) and the strategy of allowing both variable sow herd size and optional feeder pig sales ($243,432) is very small. The small difference indicates that for the confinement system, reduction in sow herd size is not needed if the option of feeder pig sales is available. The inclusion of the option of reducing sow herd size (Strategy C) basically adds only the possibility of incorrect decisions. This is why the returns in the confinement system to Strategy D for each of the other price prediction methods results in lower returns than Strategy B. The returns to the pasture system using the perfect price predictor show a much greater difference in returns between Strategy B and Strategy D. This indicates that, given an accurate price predictor, the option of reducing sow numbers is a valuable addition to the pasture system, even when feeder pig sales are included.

Naive Predictor

The naive predictor assumes future hog prices will be the same as current prices. There is a definite negative benefit or cost associated with using the naive price prediction model to make flexibility decisions. The net revenues for this predictor are lower than the nonflexible strategy for both the pasture and confinement systems. Revenue associated with the naive predictor is highest when only feeder pig sales are flexible (Strategy B) and lowest when complete production and marketing flexibility (Strategy F) is assumed for both systems.

The accumulated returns associated with the confinement system are all positive but considerably less than Strategy A. The reason that returns are lower than for the nonflexible strategy is that the naive price predictor triggered what later turned out to be wrong production and marketing decisions. For both the pasture and confinement systems, the greatest return using a naive predictor is associated with a management strategy that considers only optional feeder pig sales. The two strategies which allow for expansion beyond the design capacity yield negative returns to the pasture system. Although these returns appear very low, they are not as low as they might have been. Fixed costs of the two systems were calculated to give an idea of possible variation in returns. Had the facilities been maintained but no hogs ever been raised, the pasture system would have an accumulated loss of $44,571 and the confinement system would have lost $190,450 during the ten year simulation period.

Futures Market Predictor

The futures market predictor uses live hog futures contract prices from the Chicago Mercantile Exchange as the basis for decision making. In all cases, the futures market predictor yields returns inferior to the nonflexible strategy. The greatest returns from using the futures market as a price predictor for both the pasture and confinement systems are from Strategy B--optional feeder pig sales. The lowest returns occur when Strategy F is simulated. For this forecast method, as for the naive predictor, greater amounts of flexibility tend to result in greater numbers of wrong decisions being made and consequently lower returns.

Futures Market Predictor and Hedging

Futures market prices for live hogs form the basis of production decisions for this predictor as they did for the previous one. In this case, however, pigs produced are hedged. It is assumed that the basis remains unchanged between the time the hedge is placed and when pigs are sold. As a result, the predicted price is the actual price received. By locking in the price on which management decisions are based, hedging combined with flexible production offers the possibility of increasing net returns over some nonhedging strategies.

In no case are the returns from hedging superior to the nonflexible strategy or to what would have been earned had the pigs not been hedged. When the strategy of optional feeder pig sales is considered, the hedge is placed when the pigs reach 50 pounds or 16 weeks prior to marketing. When the feeder pig sales option is not included (Strategy C), the pigs are hedged when the sows are bred, 46 weeks prior to marketing. The different hedging periods account for most of the differences in the returns. During the 1970s, the long term futures market price consistently underestimated hog prices. The mean price for 230 pound market hogs at Oklahoma City during the 1970s is $37.90. The mean of the futures price (adjusted for an Oklahoma City basis) for delivery in 16 weeks is $36.84. The mean of the 46 week ahead futures price for the period is $34.28. As a result, hedging pigs at 50 pounds results in a slightly lower average price received than not hedging. Hedging at breeding results in a sharply lower price received since the 46 week futures price is used. Hedging also involves the payment of brokerage fees. The lowest returns of any strategies tested occurs when Strategy C is followed and the pigs are hedged 46 weeks prior to slaughter. This is due to the low price which is locked-in by the early hedge.

There is a peculiar relationship between the returns to the naive price predictor and the futures market predictor. The futures market is used to predict prices for five strategies with hedging and five without for each system. Nine of the ten returns using the futures market predictor for the pasture system are greater than the corresponding returns to the naive predictor. However, only two of the ten returns to the futures market predictor in the confinement system are greater than the returns to the naive predictor.

Causal Predictor

The causal predictor attempts to duplicate the cause and effect relationships which determine market hog prices. Explanatory variables used are trend, season, and lags of hog slaughter, sow slaughter, breeding hog inventory, and the hog-corn ratio. In all cases except one, the causal predictor yields returns greater than the nonflexible strategy. Combining the causal predictor and sow number flexibility (Strategy C) in the confinement system resulted in slightly lower returns than the nonflexible, constant full capacity strategy. The greatest returns for the pasture system using the causal predictor results when Strategy F is simulated. Strategy E gives the greatest returns for the confinement system. The causal predictor out-performs the naive predictor and both versions of the futures market price predictor.

Cyclical Predictor

The cyclical predictor uses trend and cycles to predict hog prices. Both market hog and feeder pig prices are predicted using a linear trend and three cycles of lengths 6 months, 2.75 years, and 9.0 years. The simulation using the cyclical price predictor yields returns superior to both the nonflexible strategy and the causal predictor for all three types of flexibility for both the pasture and confinement systems. For both systems Strategy F gives the greatest returns, while the strategy allowing only optional reductions in sow numbers (Strategy C) gives the lowest returns. For the cyclical predictor, as for the perfect predictor, increased flexibility results in increased returns.

Measures of Desirability

In addition to accumulated returns, other measures of performance are desirable to compare price prediction methods and management strategies. Four other measures of desirability are presented--the standard deviation of annual net cash flows, maximum debt load, payback period, and the number of years with negative net cash flow. Performance measures for the pasture system are presented in Table XX. Measures for the confinement system are given in Table XXI. There appears to be no clear-cut relationship between the standard deviation of annual net cash flows and accumulated total returns. All strategies result in wide fluctuations of annual cash flows. This variation appears to be independent of the price prediction method used but related to the type of production flexibility being simulated. The greatest standard deviation for each price prediction method occurs when the option of feeder pig purchases and sales with sow herd size

TABLE XX

ACCUMULATED RETURNS, STANDARD DEVIATION OF ANNUAL CASH FLOWS, MAXIMUM DEBT LOAD, PAYBACK PERIOD, AND YEARS WITH NEGATIVE CASH FLOW USING SELECTED MANAGEMENT STRATEGIES FOR A 40 SOW FARROW-TO-FINISH PASTURE SYSTEM, OKLAHOMA 1970-1979

Price Prediction Method	Type of Flexibility	Accumulated Ten Year Returns ($)	Standard Deviation of Annual Cash Flows ($)	Maximum Debt Load ($)	Payback Period (weeks)	Years With Negative Cash Flow (No.)
Naive	Strategy B	17,883	12,651	43,938	490	5
	Strategy C	5,214	13,654	48,755	523	4
	Strategy D	3,759	15,831	52,866	523	6
	Strategy E	-11,695	18,784	75,223	Failed[a]	7
	Strategy F	-17,159	21,891	103,657	Failed[a]	7
Futures Market	Strategy B	30,218	10,196	41,827	321	4
	Strategy C	13,130	17,215	40,848	339	4
	Strategy D	17,203	15,730	39,616	321	5
	Strategy E	16,183	14,648	62,368	325	5
	Strategy F	-11,824	21,355	82,896	365	5
Hedging	Strategy B	29,376	9,720	43,617	321	3
	Strategy C	-21,505	16,568	54,533	Failed[a]	5
	Strategy D	9,639	15,545	43,351	321	5
	Strategy E	14,988	13,465	60,721	347	6
	Strategy F	-13,007	21,909	89,798	378	5
Causal	Strategy B	54,355	11,514	41,807	318	2
	Strategy C	48,806	11,887	38,833	217	4
	Strategy D	52,681	12,790	40,817	217	3
	Strategy E	48,381	17,308	58,535	321	3
	Strategy F	69,462	21,776	70,623	196	4

TABLE XX (Continued)

Price Prediction Method	Type of Flexibility	Accumulated Ten Year Returns ($)	Standard Deviation of Annual Cash Flows ($)	Maximum Debt Load ($)	Payback Period (weeks)	Years With Negative Cash Flow (No.)
Cyclical	Strategy B	60,880	13,261	39,853	308	4
	Strategy C	53,488	11,519	40,084	321	4
	Strategy D	64,076	13,696	38,720	201	4
	Strategy E	63,238	19,497	54,990	334	6
	Strategy F	97,098	26,246	66,265	191	6
Perfect	Strategy B	63,940	11,827	41,143	308	2
	Strategy C	67,624	12,241	35,631	217	3
	Strategy D	76,862	12,127	36,689	193	2
	Strategy E	71,153	17,393	53,960	321	4
	Strategy F	110,603	22,543	64,543	191	3
None	Strategy A	44,515	11,596	45,076	335	3

[a]Management strategy failed to generate sufficient returns to eliminate debt during the simulated period.

TABLE XXI

ACCUMULATED RETURNS, STANDARD DEVIATION OF ANNUAL CASH FLOWS, MAXIMUM DEBT LOAD, PAYBACK PERIOD, AND YEARS WITH NEGATIVE CASH FLOW USING SELECTED MANAGEMENT STRATEGIES FOR A 90 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM, OKLAHOMA 1970-1979

Price Prediction Method	Type of Flexibility	Accumulated Ten Year Returns ($)	Standard Deviation of Annual Cash Flows ($)	Maximum Debt Load ($)	Payback Period (weeks)	Years With Negative Cash Flow (No.)
Naive	Strategy B	151,523	39,011	142,495	366	3
	Strategy C	130,132	37,342	152,100	445	3
	Strategy D	116,885	42,607	149,503	437	3
	Strategy E	131,667	48,590	168,231	437	3
	Strategy F	103,802	54,610	188,020	438	3
Futures Market	Strategy B	145,702	34,817	142,100	326	2
	Strategy C	110,888	38,214	147,734	373	3
	Strategy D	101,249	39,240	141,439	326	3
	Strategy E	142,774	43,268	159,437	327	3
	Strategy F	70,658	52,701	168,015	374	4
Hedging	Strategy B	139,009	36,366	140,806	326	2
	Strategy C	30,127	36,755	140,195	523	5
	Strategy D	87,320	40,806	140,145	368	3
	Strategy E	136,000	44,805	158,143	358	3
	Strategy F	65,859	54,765	172,074	377	4
Causal	Strategy B	213,540	37,215	140,587	318	2
	Strategy C	177,227	38,138	137,377	341	4
	Strategy D	209,674	38,459	140,019	318	2
	Strategy E	226,080	46,413	162,051	326	3
	Strategy F	232,760	55,093	170,114	325	4

TABLE XXI (Continued)

Price Prediction Method	Flexibility	Accumulated Ten Year Returns ($)	Standard Deviation of Annual Cash Flows ($)	Maximum Debt Load ($)	Payback Period (weeks)	Years With Negative Cash Flow (No.)
Cyclical	Strategy B	220,820	44,703	141,609	309	3
	Strategy C	183,840	35,191	140,562	333	2
	Strategy D	218,075	45,260	141,117	309	3
	Strategy E	240,517	54,469	158,932	309	4
	Strategy F	262,131	63,204	169,544	309	5
Perfect	Strategy B	242,701	38,826	139,556	302	2
	Strategy C	202,133	36,019	131,967	317	3
	Strategy D	243,432	38,829	136,953	302	2
	Strategy E	279,039	47,637	155,552	302	2
	Strategy F	310,125	52,987	157,746	302	3
None	Strategy A	117,919	36,864	148,663	341	2

variability from zero to capacity plus ten (Strategy F) is simulated. In all cases except two (futures market price predictor with and without hedging in the pasture system), the second greatest deviation in annual cash flows for each price prediction method occurs when Strategy E (feeder pig sales and sow variable from capacity to capacity plus ten) is simulated. Since these two strategies allow larger herd size, it is reasonable that they would lead to greater variance in annual cash flows.

Although one might expect the standard deviation of annual net cash flows to be inversely correlated with accumulated total returns, this is not the case. The objective of the model is to equate expected marginal costs with expected marginal revenues, and thereby maximize profits. The model makes no effort to stabilize income between calendar years. In fact, the very process of maximizing profits can lead to wider variance of annual net cash flows. Wide variation in annual cash flows is attributed to two factors. First, expenses and receipts do not necessarily occur in the same year. For example, 1973 was characterized by high hog prices and low feed prices--a profitable year for hog production. In contrast, 1974 was much less profitable. If the simulation model correctly anticipates the price changes between 1973 and 1974, it may respond by reducing the number of sows bred in the summer and fall of 1973, since the pigs produced could not be sold for a profit in 1974. The effect of this will be to increase the already high 1973 returns through sales of cull sows and lower feed and labor expenses and to reduce the returns when the pigs would have been sold in 1974. Such a decision increases long term profits, but it also increases the variance of annual returns. A second method in which flexibility for profit maximization can increase annual income variance is through the timing of sales. Using the same example, selling feeder pigs in the fall of 1973 rather than marketing them as slaughter hogs in early 1974 may increase total profits, but it also adds to income variance.

The maximum debt load does not appear to be related to accumulated returns. It is, however, related to the type of flexibility simulated and the price prediction method used. For each price prediction method, the greatest debt occurs when Strategy F (feeder pig sales and purchases and sows variable from zero to capacity plus ten) is modeled. The second greatest debt load occurs when Strategy E is simulated. This is expected since these two strategies require additional investment in facilities and livestock. For similar strategies, the maximum debt load is greater for the naive predictor than for the futures market predictor which, in turn, is greater than for the perfect price predictor.

As expected, there appears to be an inverse relationship between the total accumulated returns and the payback period. Strategies which produce greater total returns generally result in shorter payback periods. For both systems, all of the strategies which produce greater returns than the nonflexible strategy have payback periods at least as short as the nonflexible strategy. The shortest payback period for the pasture system is 191 weeks. It results when Strategy F is simulated with either the cyclical or perfect price predictor. The shortest payback period for the confinement system (302 weeks) occurs when the perfect predictor is used with Strategies B, D, E, or F. The longest payback period in the confinement system (523 weeks) results from Strategy C being used with the futures market predictor and hedging. This is the same combination which gave the lowest returns of all strategies tested for the confinement system. Three strategies fail to generate sufficient revenue in the ten year period to liquidate debt for the pasture system. The three strategies are E and F using the naive price predictor and Strategy C (sow numbers variable from zero to capacity) using the futures market predictor and hedging.

The number of years with negative net cash flow appears to be somewhat related to accumulated returns. The strategies which produce greater returns tend to have fewer years with sub-zero cash flow, although there are some notable exceptions. Strategy F using the cyclical price predictor produces the third highest returns of any strategy tested for the confinement system, yet it also has five years with negative net cash flow. Only one other strategy (C and hedging) produce as many years with negative cash flow in the confinement system. There are two strategies which result in seven years with negative cash flow in the pasture system. They are Strategies E and F using the naive price predictor. The fewest number of years with negative cash flow is two. A variety of strategies in both systems produce only two years with negative cash flow.

Management Strategies

Tables XXII through XXXI present accumulated returns, number of farrowings, and disposition of pigs produced for the five management strategies incorporating production and/or marketing flexibility and the strategy of constant production at full capacity for both systems. Table XXII shows results associated with optional feeder pig sales (Strategy B) for the pasture system. The simulation results for the confinement system using Strategy B are presented in Table XXIII.

TABLE XXII

ACCUMULATED RETURNS (1970-1979) AND SALE OF LITTERS IN A PASTURE FARROW-TO-FINISH SWINE ENTERPRISE WITH OPTIONAL FEEDER PIG SALES (STRATEGY B)

	Unit	Price Predictor Used						
		None[a]	Naive Futures	Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$44,515	$17,883	$30,218	$29,376	$54,355	$60,880	$63,940
Farrowings Possible	no.	39	39	39	39	39	39	39
Farrowings Completed	no.	39	39	39	39	39	39	39
Litters sold as:								
Slaughter hogs	no.	37	21	20	20	24	22	24
Feeder pigs	no.	0	17	18	18	14	15	14
Litters unsold	no.	2	1	1	1	1	2	1

[a]Assumes constant production at full capacity and sale of slaughter hogs only.

TABLE XXIII

ACCUMULATED RETURNS (1970-1979) AND SALE OF LITTERS IN A CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISE WITH OPTIONAL FEEDER PIG SALES (STRATEGY B)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$177,919	$151,523	$145,702	$139,009	$231,540	$220,820	$242,701
Farrowings Possible	no.	63	63	63	63	63	63	63
Farrowings Completed	no.	63	63	63	63	63	63	63
Litters sold as:								
Slaughter hogs	no.	60	38	32	32	37	39	40
Feeder pigs	no.	0	24	29	29	25	23	22
Litters unsold	no.	3	1	2	2	1	1	1

[a]Assumes constant production at full capacity and sale of slaughter hogs only.

Between 35 and 48% of the litters sold are marketed as feeder pigs for both systems regardless of the price prediction method used. For both systems the greatest number of litters are sold as feeder pigs when the futures market is used as the price predictor. This indicates that the futures market is consistently underestimating the price of market hogs in 16 weeks. None of the price prediction methods results in fewer feeder pigs being sold than does the perfect predictor.

The key determinant of profit is not reflected in these tables. The difference between low and high returns is not so much achieving the proper ratio between sales of feeder pigs and slaughter hogs as the proper timing of when to sell feeder pigs. Timing of marketing is crucial to success. For example, using the perfect price predictor and the pasture system, the model indicated that feeder pigs should be sold 14 times. The naive predictor for the pasture system sold feeder pigs 17 times. Further analysis shows that seven of the 14 times that the perfect predictor caused feeder pigs to be sold, the naive model also sold feeder pigs. Despite agreeing with the perfect model seven out of 17 times, the net returns using the naive predictor are less than one-third of returns to the perfect predictor.

For Strategy B, as for subsequent ones, the production decisions made by the futures market and hedging predictors are identical. This is because the hedging simulation uses the futures market prices for its forecasts. The only differences between the two is whether or not pigs are hedged and therefore, returns.

The returns and number of sows farrowed when herd size is allowed to vary from zero to capacity (Strategy C) for the pasture and confinement systems are presented in Tables XXIV and XXV, respectively. Both

TABLE XXIV

ACCUMULATED RETURNS (1970-1979) AND NUMBER OF SOWS FARROWING IN A PASTURE FARROW-TO-FINISH SWINE ENTERPRISE WITH THE OPTION TO REDUCE THE NUMBER OF SOWS PER FARROWING (STRATEGY C)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	\$44,515	\$ 5,214	\$13,130	-\$21,505	\$48,806	\$53,448	\$67,624
Farrowings Possible	no.	39	39	39	39	39	39	39
Farrowings Completed	no.	39	29	27	27	28	33	29
Number of Sows Farrowed:								
0	no.		10	12	12	11	6	10
1-5	no.							1
6-10	no.						1	
11-15	no.		1	1	1		1	
16-19	no.							
20	no.	39	28	26	26	28	31	28

[a]Assumes constant production at full capacity.

TABLE XXV

ACCUMULATED RETURNS (1970-1979) AND NUMBER OF SOWS FARROWING IN A CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISE WITH THE OPTION TO REDUCE THE NUMBER OF SOWS PER FARROWING (STRATEGY C)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$177,919	$130,132	$110,888	$30,127	$177,227	$183,840	$202,133
Farrowings Possible	no.	63	63	63	63	63	63	63
Farrowings Completed	no.	63	56	56	56	53	59	50
Number of Sows Farrowed:								
0	no.		7	7	7	10	4	13
1-5	no.						1	
6-10	no.			1	1	1		
11-15	no.			1	1		1	
16-20	no.							
21-25	no.		1	2	2			
26-29	no.		2	1	1			
30	no.	63	53	51	51	52	56	50

[a]Assumes constant production at full capacity.

the naive and perfect price prediction methods indicate that the pasture system should skip ten breeding periods during the 1970s. Despite similarity of numbers, the two methods differ widely in their net returns ($5,215 for the naive model versus $62,624 for the perfect predictor). Again, the key difference is the timing of the production adjustments. This can be observed by noting that the cyclical price prediction method results in returns much higher than the naive predictor for both the pasture and confinement systems, even though the naive predictor more nearly matches the perfect predictor on number of sows farrowed. Figure 15 graphically illustrates the relationship between the number of sows farrowed using the perfect and naive price predictors. The two forecasts result in the same decisions being made--only at different times. The changes in sow numbers triggered by the naive predictor tend to lag about 39 weeks behind changes made by the perfect price predictor.

The results of simulating Strategy D, which combines Strategies B and C, for the pasture and confinement systems are given in Tables XXVI and XXVII, respectively. The simulation using the perfect predictor indicates that approximately one-third of the litters produced by the confinement system should be marketed as feeder pigs. Twenty-eight percent of the litters produced in the pasture system are sold as feeder pigs.

Sixty-three farrowings are possible for the confinement system during the simulated period. One time the perfect predictor indicates that the expected returns from breeding and farrowing a group of females is less than zero. At this time, the sows scheduled for breeding are sold. Twice the model indicates that farrowing sows is profitable, but that farrowing gilts is not. As a result, no

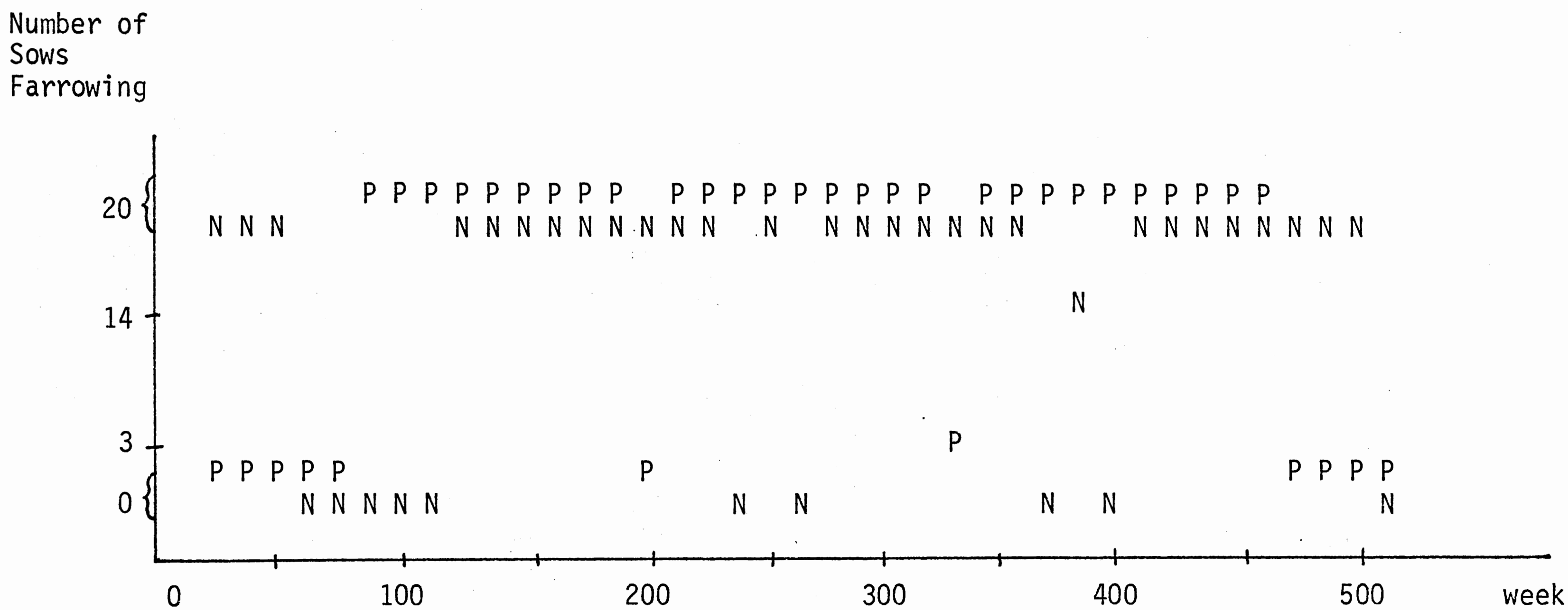

Figure 15. Number of Sows Farrowing with Perfect (P) and Naive (N) Predictors Using Pasture System and Strategy C

TABLE XXVI

ACCUMULATED RETURNS (1970-1979), NUMBER OF SOWS PER FARROWING AND SALE OF LITTERS IN A PASTURE FARROW-TO-FINISH SWINE ENTERPRISE WITH CAPABILITY OF REDUCING SOW NUMBERS AND SELLING FEEDER PIGS OR SLAUGHTER HOGS (STRATEGY D)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$44,515	$ 3,759	$17,203	$ 9,639	$52,681	$64,076	$76,862
Farrowings Possible	no.	39	39	39	39	39	39	39
Farrowings Completed	no.	39	31	27	27	37	27	32
Number of Sows Farrowed:								
0	no.		8	12	12	2	2	7
6-10	no.					2	1	
FP[b]	no.							
SH[b]	no.					(2)	(1)	
US[b]	no.							
11-15	no.		1	1	1			
FP	no.			(1)	(1)			
SH	no.		(2)					
US	no.							
16-19	no.						1	
FP	no.						(1)	
SH	no.							
US	no.							

TABLE XXVI (Continued)

	Unit	Price Predictor Used						
		None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Number of Sows Farrowed (cont.)								
20	no.	39	30	26	26	35	35	32
FP			(11)	(10)	(10)	(12)	(12)	(9)
SH		(37)	(19)	(16)	(16)	(22)	(21)	(23)
US		(2)				(1)	(2)	

[a]Assumes constant production at full capacity and sale of slaughter hogs.

[b]Numbers in parenthesis represent the number of farrowing groups sold as feeder pigs (FP), slaughter hogs (SH), and remaining unsold (US) at the end of the simulation period.

TABLE XXVII

ACCUMULATED RETURNS (1970-1979), NUMBER OF SOWS PER FARROWING AND SALE OF LITTERS IN A CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISE WITH CAPABILITY OF REDUCING SOW NUMBERS AND SELLING FEEDER PIGS OR SLAUGHTER HOGS (STRATEGY D)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$177,919	$116,885	$101,249	$87,320	$209,674	$218,075	$243,432
Farrowings Possible	no.	63	63	63	63	63	63	63
Farrowings Completed	no.	63	58	56	56	63	62	62
Number of Sows Farrowed:								
0	no.		5	7	7		1	1
1-10	no.		1	1	1			
FP[b]	no.							
SH[b]	no.			(1)	(1)			
US[b]	no.		(1)					
11-20	no.		1	1	1	1		
FP	no.							
SH	no.		(1)	(1)	(1)	(1)		
US	no.							
21-29	no.		2	3	3	1		2
FP	no.		(2)	(2)	(2)	(1)		(1)
SH	no.		(0)	(1)	(1)			(1)
US	no.		(0)					

TABLE XXVII (Continued)

	Unit	Price Predictor Used						
		None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Number of Sows Farrowed (Cont.):								
30	no.	63	54	51	51	61	62	60
FP	no.	(0)	(19)	(23)	(23)	(24)	(22)	(20)
SH	no.	(63)	(35)	(27)	(27)	(36)	(39)	(39)
US	no.	(0)	(0)	(1)	(1)	(1)	(1)	(1)

[a]Assumes constant production at full capacity and sale of slaughter hogs.

[b]Numbers in parenthesis represent the number of farrowing groups sold as feeder pigs (FP), slaughter hogs (SH), and remaining unsold (US) at the end of the simulation period.

replacement gilts are added to the herd and less than 30 sows are farrowed. Of the 39 farrowings possible for the pasture system over the ten year period, 32 times the maximum number of sows (20) are farrowed, and seven times no sows are farrowed.

With perfect market information, a producer using the pasture system should have farrowed three more groups of sows, assuming the option to reduce sow numbers and sell feeder pigs (Strategy D), than the producer who can reduce sow numbers but sells only market hogs (Strategy C). The option of selling feeder pigs increases returns by $9,000. Returns to the pasture system are increased approximately $32,000, assuming perfect market information when a producer has the option of reducing sow numbers and marketing feeder pigs (Strategy D), compared to the strategy of constant production at full capacity. For a perfect price predictor and the confinement system, the addition of feeder pig sales to variable sow numbers results in 12 more sow groups being farrowed and an additional $41,000 in returns. Compared to the nonflexible strategy, the additional flexibility (Strategy D) in combination with a perfect price predictor boosts returns by over $65,000.

Strategy E allows optional feeder pig sales and sow farrowings at the designed capacity level plus up to ten extra sows per farrowing group. The production responses to Strategy E are presented in Tables XXVIII and XXIX for the pasture and confinement systems, respectively. The causal price predictor initiates an expansion in sow herd size the most number of times (30 for the pasture systems and 50 for the confinement system) of any price forecast method. The fewest number of farrowings at the expanded level occur when the futures market is used as a price predictor. As in the previous tables, the naive predictor

TABLE XXVIII

ACCUMULATED RETURNS (1970-1979), NUMBER OF SOWS PER FARROWING AND SALE OF LITTERS IN A PASTURE FARROW-TO-FINISH SWINE ENTERPRISE WITH CAPABILITY OF EXPANDING SOW NUMBERS AND SELLING FEEDER PIGS OR SLAUGHTER HOGS (STRATEGY E)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$44,515	-$11,695	$16,183	$14,988	$48,381	$63,238	$71,153
Farrowings Possible	no.	39	39	39	39	39	39	39
Farrowings Completed	no.	39	39	39	39	39	39	39
Number of Sows Farrowed:								
20	no.	39	13	20	20	9	16	11
FP[b]	no.		(7)	(14)	(14)	(5)	(8)	(6)
SH[b]	no.	(37)	(5)	(5)	(5)	(3)	(6)	(4)
US[b]	no.	(2)	(1)	(1)	(1)	(1)	(2)	(1)
30	no.		26	19	19	30	23	28
FP	no.		(10)	(6)	(6)	(9)	(7)	(8)
SH	no.		(16)	(13)	(13)	(21)	(16)	(20)

[a]Assumes constant production at full capacity and sale of slaughter hogs.

[b]Numbers in parenthesis represent the number of farrowing groups sold as feeder pigs (FP), slaughter hogs (SH), and remaining unsold (US) at the end of the simulation period.

TABLE XXIX

ACCUMULATED RETURNS (1970-1979), NUMBER OF SOWS PER FARROWING AND SALE OF LITTERS IN A CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISE WITH CAPABILITY OF EXPANDING SOW NUMBERS AND SELLING FEEDER PIGS OR SLAUGHTER HOGS (STRATEGY E)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$177,919	$131,667	$142,774	$136,000	$226,080	$240,517	$279,039
Farrowings Possible	no.	63	63	63	63	63	63	63
Farrowings Completed	no.	63	63	63	63	63	63	63
Number of Sows Farrowed:								
30	no.							
30	no.	63	15	28	28	13	15	14
FP[b]	no.		(9)	(17)	(17)	(10)	(10)	(9)
SH[b]	no.	(60)	(5)	(10)	(10)	(2)	(4)	(4)
US[b]	no.	(3)	(1)	(1)	(1)	(1)	(1)	(1)
40	no.		48	35	35	50	48	49
FP	no.		(15)	(12)	(12)	(15)	(13)	(13)
SH	no.		(33)	(22)	(22)	(35)	(35)	(36)
US	no.			(1)	(1)			

[a]Assumes constant production at full capacity and sale of slaughter hogs.

[b]Numbers in parenthesis represent the number of farrowing groups sold as feeder pigs (FP), slaughter hogs (SH), and remaining unsold (US) at the end of the simulation period.

appears to be quite similar to the perfect predictor in all respects except accumulated returns.

Complete production and marketing flexibility (Strategy F) is a definite asset when prices are known with certainty. Tables XXX and XXXI show production levels for the pasture and confinement systems, respectively. Using the perfect predictor, Strategy F generated returns 55 and 11% greater than Strategy E for the pasture and confinement systems, respectively. There appear to be two reasons for this. First, during periods when raising hogs is unprofitable, the model allows reduction in sow numbers. Second, when finishing hogs is profitable, additional feeder pigs are purchased. Strategy F allows complete flexibility with respect to production and marketing options. With perfect knowledge, 33 groups of sows are farrowed by the pasture system. Twenty-seven of the 33 times the number of sows farrowed is increased ten above the initial design capacity of the system. Nine of the 33 farrowing groups are sold as feeder pigs and the remainder as slaughter hogs. Fourteen times feeder pigs are purchased and fed. The returns associated with complete production and marketing flexibility are almost 2.5 times as great as those associated with a constant output fixed capacity system. To the contrary, the lowest returns for both the naive and futures market without hedging price predictors occurs when Strategy F is simulated.

The relative timing of changes in sow herd size between using the perfect predictor and the naive price predictor is depicted in Figure 16. Reduction and expansion in sow numbers when the naive predictor is used tend to occur about 39 weeks after corresponding decisions made by the perfect price predictor.

TABLE XXX

ACCUMULATED RETURNS (1970-1979), FEEDER PIGS PURCHASED, NUMBER OF SOWS PER FARROWING, AND SALE OF PRODUCED LITTERS IN A PASTURE FARROW-TO-FINISH SWINE ENTERPRISE WITH COMPLETE PRODUCTION AND MARKETING FLEXIBILITY (STRATEGY F)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$44,515	-$17,159	-$11,824	-$13,007	$69,462	$97,098	$110,603
Farrowings Possible	no.	39	39	39	39	39	39	39
Farrowings Completed	no.		37	27	27	34	37	33
Number of Sows Farrowed:								
0	no.		2	12	12	5	2	6
1-10	no.					2		
FP[b]	no.					(1)		
SH[b]	no.							
US[b]	no.					(1)		
11-15	no.		1	1	1	1		
FP	no.		(1)	(1)	(1)	(1)		
SH	no.							
US	no.							
16-19	no.		1				1	
FP	no.		(1)				(1)	
SH	no.							
US	no.							
20	no.	39	9	7	7	1	13	6
FP	no.		(4)	(4)	(4)		(5)	(1)
SH	no.	(37)	(4)	(3)	(3)	(1)	(6)	(4)
US	no.	(2)	(1)				(2)	(1)

TABLE XXX (Continued)

	Unit	Price Predictor Used						
		None[a]	Naive	Futures Market	Heading	Causal	Cyclical	Perfect
Number of Sows Farrowed (Cont.):								
30	no.		26	19	19	30	23	27
FP	no.		(10)	(6)	(6)	(9)	(7)	(8)
SH	no.		(16)	(13)	(13)	(21)	(16)	(19)
US	no.							
Feeder Pigs Purchased	no.	0	8	7	7	15	15	14

[a]Assumes constant production at full capacity and sale of slaughter hogs.

[b]Numbers in parenthesis represent the number of farrowing groups sold as feeder pigs (FP), slaughter hogs (SH), and remaining unsold (US) at the end of the simulation period.

TABLE XXXI

ACCUMULATED RETURNS (1970-1979), FEEDER PIGS PURCHASED, NUMBER OF SOWS PER FARROWING, AND SALE OF PRODUCED LITTERS IN A CONFINEMENT FARROW-TO-FINISH SWINE ENTERPRISE WITH COMPLETE PRODUCTION AND MARKETING FLEXIBILITY (STRATEGY F)

		Price Predictor Used						
	Unit	None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Accumulated Returns	dollars	$44,515	$103,802	$70,658	$65,859	$232,760	$262,131	$310,125
Farrowings Possible	no.	63	63	63	63	63	63	63
Farrowings Completed	no.	63	58	56	56	61	61	57
Number of Sows Farrowed:								
0	no.		5	7	7	2	2	6
1-10	no.			2	2	1		
FP[b]	no.					(1)		
SH[b]	no.			(2)	(2)			
US[b]	no.							
11-20	no.		2	1	1			
FP	no.			(1)	(1)			
SH	no.		(1)					
US	no.		(1)					
21-29	no.		1	2	2		2	
FP	no.		(1)	(1)	(1)		(2)	
SH	no.			(1)	(1)			
US	no.			(1)	(1)			
30	no.	63	7	16	16	10	11	8
FP	no.		(5)	(11)	(11)	(8)	(6)	(4)
SH	no.	(60)	(2)	(5)	(5)	(1)	(4)	(3)
US	no.	(3)				(1)	(1)	(1)

TABLE XXXI (Continued)

	Unit	Price Predictor Used						
		None[a]	Naive	Futures Market	Hedging	Causal	Cyclical	Perfect
Number of Sows Farrowed (Cont.):								
40	no.		48	35	35	50	48	49
FP	no.		(15)	(12)	(12)	(15)	(13)	(13)
SH	no.		(33)	(22)	(22)	(35)	(35)	(36)
US	no.			(1)	(1)			
Feeder pigs purchased	no.	0	17	11	11	23	24	24

[a]Assumes constant production at full capacity and sale of slaughter hogs.

[b]Numbers in parenthesis represent the number of farrowing groups sold as feeder pigs (FP), slaughter hogs (SH), and remaining unsold (US) at the end of the simulation period.

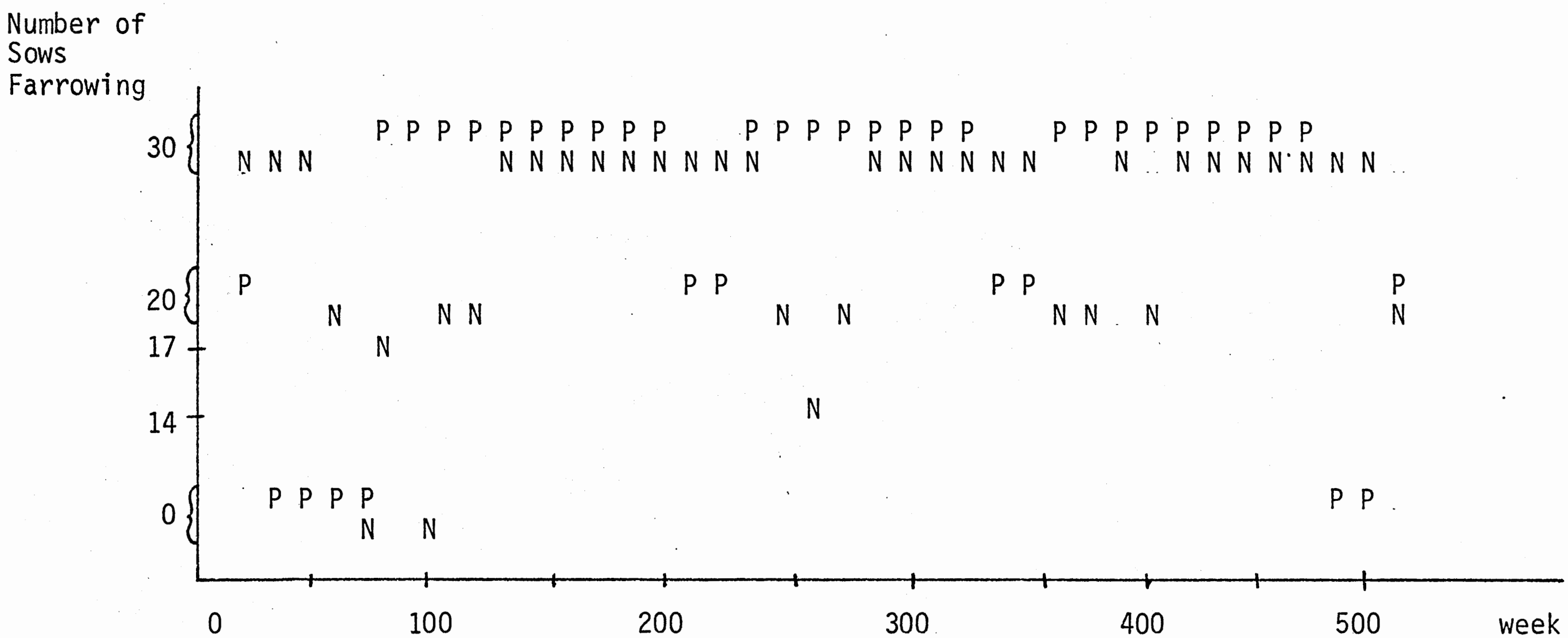

Figure 16. Number of Sows Farrowing with Perfect (P) and Naive (N) Predictors Using Pasture System and Strategy F

For the confinement system, Strategy F in combination with a perfect price predictor results in 24 groups of feeder pigs being purchased. Forty-nine of the 57 farrowings which occur consist of the maximum number of females. Seventeen groups of pigs are sold as feeders and 39 groups are marketed as slaughter hogs. One group remains at the end of the simulation period. For both systems the futures market predictors result in the fewest purchases of feeder pigs.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary of Problem and Procedure

Market hog prices historically have shown great variation. Wide fluctuation in hog prices results in even wider variation in income for hog producers. Producers often attempt to take advantage of changing prices by altering their production level, trying to have more hogs to sell when prices are high and fewer when prices are low. However, due to the time lag between production decisions and product marketing, producers often find that production adjustments occur too late to take advantage of the price trends. As a result, some doubts have arisen about the advisability of using an "in and out" method of production.

Economic theory states that profit is maximized by producing where marginal cost equals marginal revenue. For a swine producer, changing hog prices dictates changing output in order to maximize profits. The problem this research addresses is: profit is maximized by producing where marginal cost equals marginal revenue, but production lags necessitate that operating decisions be made before marginal cost and marginal revenue become known. The general objective is to determine which management strategies and price prediction methods result in the greatest profit for a farrow-to-finish swine enterprise.

The procedure used to is analyze the effectiveness of production and marketing flexibility over a historical set of circumstances.

From this, inferences can be drawn concerning management strategies which might perform well in the future. A deterministic, dynamic, profit-optimizing computer simulation model was developed which incorporated price predictions as the production control mechanism. The model was used to simulate a 40 sow pasture and a 90 sow confinement farrow-to-finish swine enterprise. Six management strategies, involving different amounts of production and marketing flexibility, and five price prediction methods were simulated by the model. Returns to land, labor, and management for combinations of management strategies and price prediction methods were determined over a ten year simulation period beginning in January, 1970.

Summary of Results

The greatest returns to the naive, futures market, and futures with hedging predictors result from using Strategy B, optional feeder pig sales only. This is true for both the pasture and confinement systems. For these price predictors, greater amounts of flexibility result in lower profits. In no case are these price predictors accurate enough to give returns superior to the nonflexible strategy. The lowest returns of any strategy tested for both the pasture and the confinement systems occurred when futures market prices were used to allow sow numbers to vary from zero to capacity (Strategy C) and the production was hedged at breeding.

For the causal, cyclical, and perfect predictors, the higher returns resulted from the strategies with greater amounts of flexibility. Strategy F, which allows feeder pig purchases and sales and sow farrowings to vary from zero to capacity plus ten, produced the greatest returns for all three of these price predictors. All management strategies using the causal, cyclical, and perfect price predictors, except one, resulted in returns which were superior to the nonflexible strategy. The exception was Strategy C for the confinement system using the causal price predictor. For the pasture system, the perfect price predictor in combination with Strategy F increased returns by 148% over the nonflexible, constant output strategy. For the confinement system the perfect predictor and Strategy F yielded returns 74% higher than the nonflexible strategy.

Relation to Theory

The relationship between profit and product price for three different production strategies was presented in Figure 9. The strategies illustrated were: holding output constant (π_0), varying output inversely with product price (π_1), and varying output directly with product price (π_2). The relationship between the simulation results for the price predictors and the profit functions depicted in Figure 9 is not exact since the simulation model did not hold production costs constant and since price predictors are not always right or always wrong. However, a general comparison can be made. The perfect, cyclical and causal predictors generally perform like profit function π_2 and result in increased profits by using production flexibility; the naive and futures market predictors behave like profit function π_1 and cause production flexibility to produce lower profits. Strategy A, which holds output constant regardless of product price, produces a profit function much like function π_0 in Figure 9. However, since costs are allowed to vary, Strategy A's profit function in not linear.

Conclusions

Producers can increase profits by adjusting output to the extent that there is a positive correlation between expected and realized prices. It is not just flexibility itself which allows for increase profits, but proper timing of the use of flexibility which is important. The simulation model using a perfect price predictor indicates that production and marketing flexibility do enhance accumulated net returns over the simulated ten year period. Assuming perfect price information and complete production and marketing flexibility, profits increase 148% for the pasture system and 74% for the confinement system over the full capacity nonflexible strategies. The greater returns tend to correspond with a shorter payback period and fewer years with a negative cash flow. The magnitude of returns, however, does not appear to affect the standard deviation associated with annual cash flows or the maximum debt load.

Net returns are substantially reduced from a full capacity strategy if current prices are used as the basis for flexibility decisions. For this naive predictor case, the greater the flexibility the lower the profits. Although using current prices to make production decisions appears to be a foolhardy strategy, the temptation to do so is quite strong. When prices and profits are high, it is very easy to expand your business. When prices are low and you are losing money, it is very difficult to muster the courage and finances to increase or even maintain production.

Basing production and marketing decisions on the futures market price gave results superior to the naive predictor but inferior to the nonflexible, full capacity strategy.

In many ways, the futures market price is the most important forecasting method modeled. It represents the most accurate price outlook information that is widely available. If the futures market adjusts to reflect the general consensus of the best information available, then it is conceptually impossible for widely available price information to consistently be more accurate than the futures market price. This being the case, it would not appear that contemporary price forecasts are sufficiently accurate to allow a farrow-to-finish swine enterprise to take advantage of the types of production and marketing flexibility examined in this research. To profitably adjust output, one must be able to consistently out-guess the crowd. Granted, the accuracy of the futures market as a price predictor may vary with time. The problem is not that swine producers are uninformed or fail to react properly to accurate price information. If this were the case, the returns to the futures market price predictor would be superior to the nonflexible strategy. The problem is that sufficiently accurate price forecasts are not available.

The regular hedging of hogs by a swine producer was not a desirable practice during the 1970s. The live hog futures market consistently underestimated the future price of hogs. Consequently, on average, the farther in advance hogs were hedged, the lower the price that was locked-in.

The large downward bias present in the futures market during the 1970s was very influential in affecting its desirability as a price predictor. The bias was particular costly to the hedging strategy. Over a long period, the futures market price would be expected to be a relatively unbias estimator of future hog prices. Therefore, it is reasonable to expect the futures market predictor to perform better in the future than it did during the 1970s. Whether or not it might be accurate enough during other periods to provide returns to flexibility which are superior to the nonflexible strategy was not determined.

The causal predictor gives returns greater than the nonflexible strategy for all options except only varying sow numbers in the confinement system.

The simulation model incorporating the cyclical hog price prediction equation is more profitable for both the pasture and confinement systems than the nonflexible strategy for all three types of flexibility. However, it must be remembered that both the causal and cyclical predictors have enhanced accuracy since they were developed using the same price data which they are predicting. Neither predictor would be expected to perform as well in predicting future hog prices.

In conclusion, the success of adaptive planning appears to be directly related to the accuracy of the price information used. The nonflexible, constant production strategy is far more profitable than production flexibility based upon inaccurate price forecasts. It appears that a method of predicting prices more accurate than the 1970s futures market is needed before flexibility as modeled in this study becomes profitable. However, if a method of predicting prices which is more accurate than the futures market can be developed, then speculating directly in the futures market might prove a quicker and less risky path to riches than raising hogs.

Limitations

There are numerous restrictions on this research and the conclusions which can be drawn. First, and most important, this was a study of the past. It is felt that the results accurately reflect what actually would have occurred during the 1970s had swine producers followed the strategies. But there is no assurance that what worked, of failed to work, in the past will do so in the future. Second, a limited number of management strategies and price prediction methods were used. Different versions might meet with more desirable results and greater profits. Third, the objective of the simulation model is to equate expected marginal cost and expected marginal revenue. Perhaps a different strategy, such as expanding production when the hog-corn ratio is low and contracting when the ratio is high would meet with success. Finally, a wide variety of assumptions were made in order to facilitate the research. Each of these present the possibility of biasing the results and conclusions.

Suggestions for Further Research

One of the obvious areas of possible further research relates to the limitations of this study. Of particular interest is the possibility of eliminating some of the assumptions which were made. Inclusion of income taxes, land use charges, and a fixed cost for labor would make the situation more realistic. In addition, feed purchases at the time of consumption rather than when production decisions are made would be more typical of actual practice for many producers.

This research assumes that production coefficients are fixed and known with certainty. How adaptive planning can be used to cope with production uncertainties and their effect on long term returns is another area of possible research. The possibility of selective hedging strategies have not been included in this study. The computer model used in this study is designed to simulate feeder pig production and finishing purchased pigs. Analysis of these types of swine enterprises should prove interesting. Finally, a study of the nature and cause of any bias present in live hog futures prices should be of interest to anyone hedging hogs or using the futures market as a price predictor.

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APPENDIX

The annual net cash flows for the 62 simulations of farrow-to-finish enterprises are presented in Tables XXXII through XLIV. The net cash flow for the nonflexible strategies are presented in Table XXXII. The cash flows for the simulations of the pasture system are given in Tables XXXIII through XXXVIII. The results for the confinement system are in Tables XXXIX through XLIV. The cash flows are listed by years. Cash flow for 1969 consists solely of the investment expense for facilities and equipment while that for 1980 is from the liquidation of assets. All asset are liquidated during the first week of 1980. The summation of the annual net cash flows equals the accumulated total returns.

TABLE XXXII

ANNUAL NET CASH FLOW USING STRATEGY A FOR THE PASTURE AND CONFINEMENT SYSTEMS (DOLLARS)

Year	Pasture Dollars	Confinement Dollars
1969	-9,282	-73,630
1970	-19,071	-51,773
1971	-9,024	-19,202
1972	4,973	11,665
1973	7,870	29,941
1974	-1,362	23,125
1975	-15,540	30,674
1976	8,524	52,938
1977	6,140	2,815
1978	7,815	55,876
1979	422	5,849
1980	31,970	109,640
Total	44,515	177,919

TABLE XXXIII

ANNUAL NET CASH FLOW FOR THE PASTURE SYSTEM USING THE NAIVE PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-9,282	-9,282	-9,282	-10,571	-10,571
1970	-13,546	-16,733	-11,368	-19,753	-19,753
1971	-4,418	4,669	196	-3,505	-183
1972	-7,301	-17,456	-17,378	-16,205	-21,294
1973	1,345	4,236	-1,442	-2,953	-4,376
1974	9,370	13,122	11,752	12,634	14,311
1975	-7,068	-8,831	-11,970	-19,573	-32,392
1976	18,225	9,500	20,560	20,742	29,042
1977	-19,119	7,007	-17,063	-18,362	-18,292
1978	5,019	-14,239	-786	-1,308	-389
1979	15,887	8,328	32,979	24,175	27,098
1980	19,770	24,892	7,560	22,985	19,641
Total	17,883	5,215	3,759	-11,695	-17,159

TABLE XXXIV

ANNUAL NET CASH FLOW FOR THE PASTURE SYSTEM USING THE FUTURES PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-9,282	-9,282	-9,282	-10,571	-10,571
1970	-11,626	-15,905	-7,621	-15,285	-11,268
1971	-12,695	-8,371	-15,439	-17,989	-20,016
1972	4,009	4,400	4,507	1,588	1,796
1973	6,146	3,453	2,318	8,240	-15,671
1974	-2,436	-2,695	-3,761	-14,581	-4,463
1975	15,528	15,717	15,631	18,915	8,275
1976	20,695	20,690	36,667	27,305	53,014
1977	959	14,977	-160	1,612	271
1978	555	-36,788	-22,409	-5,249	-28,830
1979	-1,802	3,015	9,985	-2,451	6,043
1980	20,168	23,920	6,766	24,649	9,599
Total	30,218	13,130	17,203	16,183	-11,824

TABLE XXXV

ANNUAL NET CASH FLOW FOR THE PASTURE SYSTEM USING THE FUTURES PRICE PREDICTOR WITH HEDGING (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-9,282	-9,282	-9,282	-10,571	-10,571
1970	-11,626	-13,987	-7,621	-15,285	-11,268
1971	-11,375	-5,125	-14,119	-16,669	-18,696
1972	1,635	-210	2,133	-786	-578
1973	584	-14,096	-6,464	2,677	-21,234
1974	5,824	1,150	4,195	-6,321	3,797
1975	10,605	4,892	10,364	13,992	3,352
1976	21,842	16,810	37,529	28,397	54,085
1977	849	13,063	-487	1,441	134
1978	440	-39,788	-22,788	-5,505	-29,084
1979	-286	1,147	9,420	-1,031	7,459
1980	20,167	23,920	6,759	24,649	9,599
Total	29,376	-21,505	9,639	14,988	-13,007

TABLE XXXVI

ANNUAL NET CASH FLOR FOR THE PASTURE SYSTEM USING THE CAUSAL PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-9,282	-9,282	-9,282	-10,571	-10,571
1970	-11,626	-5,359	-7,621	-14,079	-10,219
1971	-12,676	-16,259	-16,245	-21,123	-30,874
1972	4,010	3,556	4,055	1,014	1,997
1973	7,902	21,382	18,270	12,691	31,576
1974	1,466	-1,870	-6,683	-7,252	-10,533
1975	16,096	25	11,401	15,906	8,538
1976	7,678	11,697	12,239	9,391	17,868
1977	5,937	-587	695	363	-7,142
1978	8,137	14,005	8,965	10,032	27,529
1979	17,476	14,179	17,126	28,351	29,962
1980	19,236	17,320	19,762	23,656	21,332
Total	54,355	48,806	52,681	48,381	69,462

TABLE XXXVII

ANNUAL NET CASH FLOW FOR THE PASTURE SYSTEM USING THE CYCLICAL PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-9,282	-9,282	-9,282	-10,571	-10,571
1970	-17,152	-13,571	-12,915	-17,646	-13,409
1971	-5,574	-8,635	-7,825	-8,308	-19,376
1972	2,644	762	642	-4,375	-1,819
1973	22,820	14,177	25,761	32,060	50,257
1974	-10,729	-4,075	-11,823	-23,970	-31,026
1975	16,377	16,865	18,265	16,697	21,369
1976	11,269	13,160	13,860	20,615	25,709
1977	6,120	-258	3,139	-3,315	-1,513
1978	24,457	14,798	24,245	32,026	46,902
1979	-13,302	3,329	-13,194	-7,112	-5,412
1980	33,232	26,178	33,204	37,139	35,987
Total	60,880	53,448	64,076	63,238	97,098

TABLE XXXVIII

ANNUAL NET CASH FLOW FOR THE PASTURE SYSTEM USING THE PERFECT PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-9,282	-9,282	-9,282	-10,571	-10,571
1970	-17,152	-1,594	-2,459	-17,646	-2,953
1971	-5,574	-16,573	-16,647	-13,200	-31,078
1972	3,149	1,117	1,034	1,380	665
1973	9,916	15,233	13,625	15,490	33,658
1974	2,907	-4,306	1,166	-2,452	-1,110
1975	16,492	23,414	18,499	18,954	24,608
1976	11,346	4,759	11,365	17,879	5,973
1977	6,915	6,302	7,283	-2,268	6,260
1978	7,974	19,272	15,363	10,627	21,581
1979	17,938	19,178	26,343	29,914	42,844
1980	19,311	10,105	10,572	23,047	20,726
Total	63,940	67,624	76,862	71,153	110,603

TABLE XXXIX

ANNUAL NET CASH FLOW FOR THE CONFINEMENT SYSTEM USING THE NAIVE PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-73,630	-73,630	-73,630	-75,572	-75,572
1970	-42,749	-46,979	-38,485	-54,321	-51,790
1971	988	3,697	373	3,541	2,485
1972	-23,390	-33,189	-36,614	-41,036	-58,043
1973	29,684	28,635	32,757	32,354	41,834
1974	20,171	20,532	20,621	23,479	26,357
1975	17,982	23,211	8,266	9,198	-15,453
1976	65,645	47,305	67,155	69,554	91,951
1977	-15,873	-3,903	-31,556	-30,102	55,895
1978	53,631	45,927	39,806	53,850	47,133
1979	56,764	17,079	85,792	53,850	99,493
1980	62,299	101,446	42,402	71,832	51,303
Total	151,523	130,132	116,885	131,667	103,802

TABLE XL

ANNUAL NET CASH FLOW FOR THE CONFINEMENT SYSTEM USING THE FUTURES PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-73,630	-73,630	-73,630	-75,572	-75,572
1970	-29,875	-51184	-29,440	-34,393	-33,963
1971	-34,635	-18,942	-34,483	-45,227	-45,130
1972	10,944	-13,299	12,599	10,282	5,835
1973	23,221	23,034	16,664	25,256	-324
1974	16,783	17,267	12,835	11,923	15,126
1975	29,184	36,904	32,278	32,197	20,928
1976	66,545	46,651	61,399	79,140	93,987
1977	1,933	48,698	35,827	6,456	39,397
1978	19,680	-38,205	-46,870	-3,360	76,655
1979	30,276	3,612	41,139	41,922	48,562
1980	85,276	103,384	70,931	94,158	78,465
Total	145,702	110,888	101,249	142,774	70,658

TABLE XLI

ANNUAL NET CASH FLOW FOR THE CONFINEMENT SYSTEM USING THE FUTURES PRICE PREDICTOR WITH HEDGING (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-73,630	-73,630	-73,630	-75,572	-75,572
1970	-29,875	-49,985	-29,440	-34,393	-33,963
1971	-33,349	-12,110	-33,198	-43,941	-43,844
1972	7,545	3,491	9,200	6,883	2,436
1973	14,675	-7,520	4,295	16,709	-8,872
1974	23,479	24,162	19,170	18,619	21,822
1975	18,213	16,744	22,899	21,227	9,957
1976	75,628	38,232	69,934	88,191	102,961
1977	1,574	39,426	35,190	6,093	39,027
1978	16,859	-50,737	-50,883	-6,203	-77,337
1979	32,622	-1,305	42,865	44,236	50,778
1980	85,269	103,377	70,918	94,152	78,465
Total	139,009	30,127	87,320	136,000	65,859

TABLE XLII

ANNUAL NET CASH FLOW FOR THE CONFINEMENT SYSTEM USING THE CAUSAL PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-73,630	-73,630	-73,630	-75,572	-75,572
1970	-29,875	-21,510	-29,327	-35,048	-32,034
1971	032,854	-36,801	-32,839	-44,506	-54,482
1972	10,417	7,366	10,271	6,907	4,506
1973	52,070	50,534	58,473	67,900	93,271
1974	9,768	-767	1,461	-1,130	-20,571
1975	32,224	16,839	29,136	31,043	28,113
1976	52,224	62,207	54,401	62,621	66,864
1977	8,561	-4,560	6,269	2,650	-7,079
1978	80,056	62,954	82,059	95,270	104,755
1979	40,577	30,652	40,720	47,443	54,959
1980	63,939	83,943	62,679	68,503	70,029
Total	213,540	177,227	209,674	226,080	232,760

TABLE XLIII

ANNUAL NET CASH FLOW FOR THE CONFINEMENT SYSTEM USING THE CYCLICAL PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-73,630	-73,630	-73,630	-75,572	-75,572
1970	-49,140	-39,272	-44,819	-57,389	-57,962
1971	-12,454	-23,533	-16,172	-15,883	-14,565
1972	7,408	4,816	3,181	-2,055	-14,718
1973	76,620	38,306	79,823	96,638	114,580
1974	-11,720	15,488	-14,037	-24,116	-27,680
1975	62,771	36,977	64,278	71,953	77,777
1976	27,801	48,569	27,579	31,541	34,847
1977	8,939	5,662	8,484	2,939	-5,629
1978	106,527	56,057	107,095	128,407	147,116
1979	12,265	12,901	12,213	10,460	10,570
1980	65,293	101,498	64,081	73,595	73,367
Total	220,680	183,840	218,075	240,517	262,131

TABLE XLIV

ANNUAL NET CASH FLOW FOR THE CONFINEMENT SYSTEM USING THE PERFECT PRICE PREDICTOR (DOLLARS)

Year	Management Strategy				
	B	C	D	E	F
1969	-73,630	-73,630	-73,630	-75,572	-75,572
1970	-38,898	-18,641	-34,980	-39,505	-30,509
1971	-23,059	-35,768	-24,507	-35,688	-45,783
1972	12,514	351	11,648	10,688	4,769
1973	55,231	45,932	54,968	70,305	87,420
1974	13,207	16,787	12,671	8,141	12,236
1975	63,816	44,222	63,480	74,379	80,461
1976	35,569	52,461	36,026	40,423	36,206
1977	9,001	-2,500	6,656	4,287	-762
1978	82,648	58,176	85,451	100,204	110,299
1979	42,769	56,275	41,665	52,198	70,301
1980	63,533	58,449	63,983	69,180	61,060
Total	242,701	202,133	243,432	279,039	310,125

VITA 2

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