A STOCHASTIC EVALUATION OF SWINE BREEDING SCHEMES AND MANAGEMENT STRATEGIES

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PREFACE

The purpose of this study was to determine the economically superior swine breeding scheme and the impact of management on producer income. A computer model was used to simulate 27 swine breeding schemes composed of Duroc, Hampshire and Yorkshire breeds and four different management impacts on income. The results were evaluated using stochastic dominance analysis. A producer's willingness to pay to move from one scheme or strategy to another were also estimated. Production induced volatility was compared to price induced volatility to determine which has the greatest impact on producer income volatility.

I would like to thank all who assisted me in this project. Special appreciation goes to my major advisor, Dr. Joseph Williams, for his guidance and encouragement throughout my study at Oklahoma State University. I am also grateful to the other committee members, Dr. Francis Epplin, Dr. James Trapp, Dr. Archie Clutter and Dr. Larry Claypool, for their input at various stages of this work.

Special thanks are due to the Department of Agricultural Economics for the financial support of a graduate research assistantship. The help of the departmental computer services personnel, Larry Watkins, Dave Cassel, Brent Tweeten and Vickie Brake, is sincerely appreciated.

My love is expressed for my wife, Penny, and daughter, Trixie, for their involvement in my life. They were always a welcome relief from the books.

This endeavor is acknowledged as a form of worship to my Lord Jesus Christ, in whom are hidden all the treasures of wisdom and knowledge.

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CHAPTER I

INTRODUCTION

> I again saw under the sun that the race is not to the swift, and the battle is not to the warriors, and neither is bread to the wise, nor wealth to the discerning, nor favor to men of ability; for time and chance overtake them all (Ecclesiastes 9:11).

With these words, Solomon personifies the problem this thesis addresses--that of uncertainty, referred to as time and chance.

Traditional production theory assumes timelessness and perfect knowledge. These simplifying assumptions have worked well in giving economists a foundation to build theory and models. Superior analysis requires that these assumptions be relaxed to study the effect of time and uncertainty on production and production decisions.

This study begins to relax these assumptions for pork production. Since production occurs over time with one outcome affecting another, consideration of uncertainty is best studied with dynamic models. Stochastic and dynamic theories and methods devised to account for uncertainty and time are employed to help producers make decisions which will maximize their utility.

Discussion of Problem Area

Hogs are produced for their economic return to producers and are managed to maximize that return subject to various constraints. Both production and marketing performance are critical to pork production. Proforma income and cash flow statements require that production performance be estimated. Enterprise analyses (enterprise budgets) list the amount of livestock sold by class and the amount of feed used by type. This is used, in conjunction with per unit prices, to specify total value and costs of production.

Production and marketing summaries for farrow-to-finish pork producers are reported by many farm management associations. The Southwest Minnesota Farm Business Management Association (SMFBMA) particularizes the 'average for all farms,' 'average for low 20% income' and 'average for high 20% income' when more than 24 farms report in each category. Major performance standards which the SMFBMA reports are litters per sow, number born and number weaned per litter, pounds of feed per pound of gain and average dollars per hundredweight received for hogs sold (See Table 1). These traits vary among producers and with time. The traits interact with other factors to impact producer income.

In 1988, the low 20% group received a higher hog market price than the average for all farms group. Subpar breeding and feeding performance most likely accounted for the poor return to overhead costs in that year. In 1986, the low 20% group experienced higher weaning averages than either of the other groups. Low market hog price received contributed to the poor income of that group in 1986. Marketing and production interacted to determine income and its variance.

Edwards, van der Sluis and Stevermer, using Iowa producer cost and return data, reported that a definite negative correlation between profit and feed expense exists. The correlation between number of pigs weaned per sow per year and profit was not as great.

The same study found that the cost of feed had more impact on profitability than feed conversion, but both held considerable potential for reducing cost and hence increasing profits. Reproductive efficiency had a

TABLE 1

PERFORMANCE MEASURES FOR FARROW-TO-FINISH PORK PRODUCTION.

Year:	1988			1987			1986			1985		
Income Group: Trait	Average	Low	High	Average	Low	High	Average	Low	High	Average	Low	High
Litters per sow	1.72	1.58	1.88	1.70	1.73	1.95	1.69	1.9	1.77	na	na	na
No. born per litter	9.18	8.69	9.69	9.27	9.54	9.46	9.23	9.42	9.33	9.30	9.42	9.27
No. weaned per litter	7.8	6.97	8.39	8.14	7.70	8.40	7.88	8.21	8.1	7.76	8.30	7.78
Lb. feed per lb. gain	3.91	4.80	3.25	3.93	4.41	3.58	3.99	4.12	3.75	4.63	3.83	4.12
Market price ($/cwt.)	44.5	45.28	45.77	51.44	51.11	51.9	47.83	42.85	51.28	44.78	46.36	45.03

na = not reported
Source: Southwestern Minnesota Farm Business Management Association Annual Reports

greater influence on profitability than market hog price. Of the variables which determine pigs weaned per sow per year, pigs weaned per litter was more critical than litters per sow per year. The determinants of net income differ in relative importance. Edwards, et al. concluded that there is "as much or more variation in profitability among producers in a given year as there is in average profits from peak year to low year."

These business analyses do not report the breeds of swine used in various farms. However, the impact of swine breeds and crossbreeding upon production of pork is widely accepted. Different breeds have different strengths, and weaknesses. When crossbreeding schemes are used the strengths can be exploited while the weaknesses are minimized.

Dr. Gary Bennett, addressing The Third World Congress on Genetics Applied to Livestock Production, introduced his presentation with these words.

> Crossbreeding of swine is exploited widely to take advantage of heterosis, breed differences and complementarity. . . . That all pigs are not produced by the crossbreeding system with the highest heterosis is evidence that other genetic, managerial and economic considerations are important in choosing among crossbreeding systems.

Bennett's presentation continued by discussing the genetic considerations. This thesis seeks to address the managerial and economic considerations.

A major problem in deciding which breeding scheme to operate lies in the ambiguity of the pertinent data. Production traits of various breeds and marketing factors are not constant. Variances and covariances are associated with these variables.

Several studies record the production performance of various breeds and crossbreeds. Traits such as litter size, pounds of feed per pound of gain, average daily gain, carcass quality, etc. have been studied and shown to have statistically different means for different schemes. Along with the statistically different means is the variance associated with each of these traits. This variance quantifies the variability due to factors other than breed; factors such as environment and health. Management levels have been held constant in these studies and should not be a factor in the variance reported.

The conclusion is that production characteristics are not constant over time. A sow does not bear the same number of pigs with each farrowing, let alone every sow in a particular breed. Feed efficiency varies from pig to pig and from one breed to another. Variance in crucial traits exists within breeds and on the same farm. The variance of one production characteristic, when considered with the mean and variance of other characteristics and in a dynamic context, makes determination of the ideal breeding scheme difficult.

Breeding schemes can also induce profit volatility from year to year. The breed composition of a farm changes with each generation when rotational crosses are used. If the breeds in the rotation are different for important traits, wide swings in performance and profit can be expected from generation to generation . Historically rotational crosses fit production systems because they don't require purchase of replacement gilts or special matings to produce replacement gilts. Terminal crosses which don't have the above production volatility and make better use of hybrid vigor are becoming more popular as swine are more intensively managed (Ahlschwede, et al.).

Five major sources of business risk in agriculture have been identified. They are: (1) production or technical risk; (2) marketing or price risk; (3) technological risk; (4) legal and social risk; and (5) human sources of risk (Sonka and Patrick). Production risk occupies the majority of this thesis while marketing risk is considered where it interacts with production. The other risks are not discussed.

When the variance of production traits is considered simultaneously with the variance of marketing factors, management decisions become more difficult. Historically, the marketing factors have been given the greatest attention in stochastic analysis (Cleveland, Guiterrez, Bailey, D. V. et.al. and Conner, et.al.). Price fluctuations of major inputs, such as feed, and outputs, such as market hogs, contribute to whole firm income volatility. Production performance also varies from year to year and affects whole firm income volatility. Variance causes confusion and inefficiency.

The volatility of net income from pork production is a well documented phenomenon. Futrell publishes a monthly report detailing the revenue and expenses associated with both feeder pig production, feeder pig finishing, and farrow-to-finish systems. Futrell assumes constant production performance in his research, allowing only prices to change over time. Figure 1 shows the profit per head and demonstrates that income to Iowa pork producers fluctuates over time. This fluctuation is attributable primarily to price changes.

The determinants of net income fluctuate, causing the net income to move. Several of these determinants may simultaneously move in the same direction. Other determinants may simultaneously move in opposite directions. This movement of determinants such as market price of hogs or feed costs can cause both extremely high incomes or extremely low incomes.

The diverse causes of production and marketing volatility complicate any study of income volatility. Weather may cause grain yields to decrease, hence causing feed costs to rise; disease may decrease production; the aggregate of management decisions can influence supply, affecting price; season can change sow performance; public policies can alter the markets available to producers or alter the way income is calculated. The events affecting prices

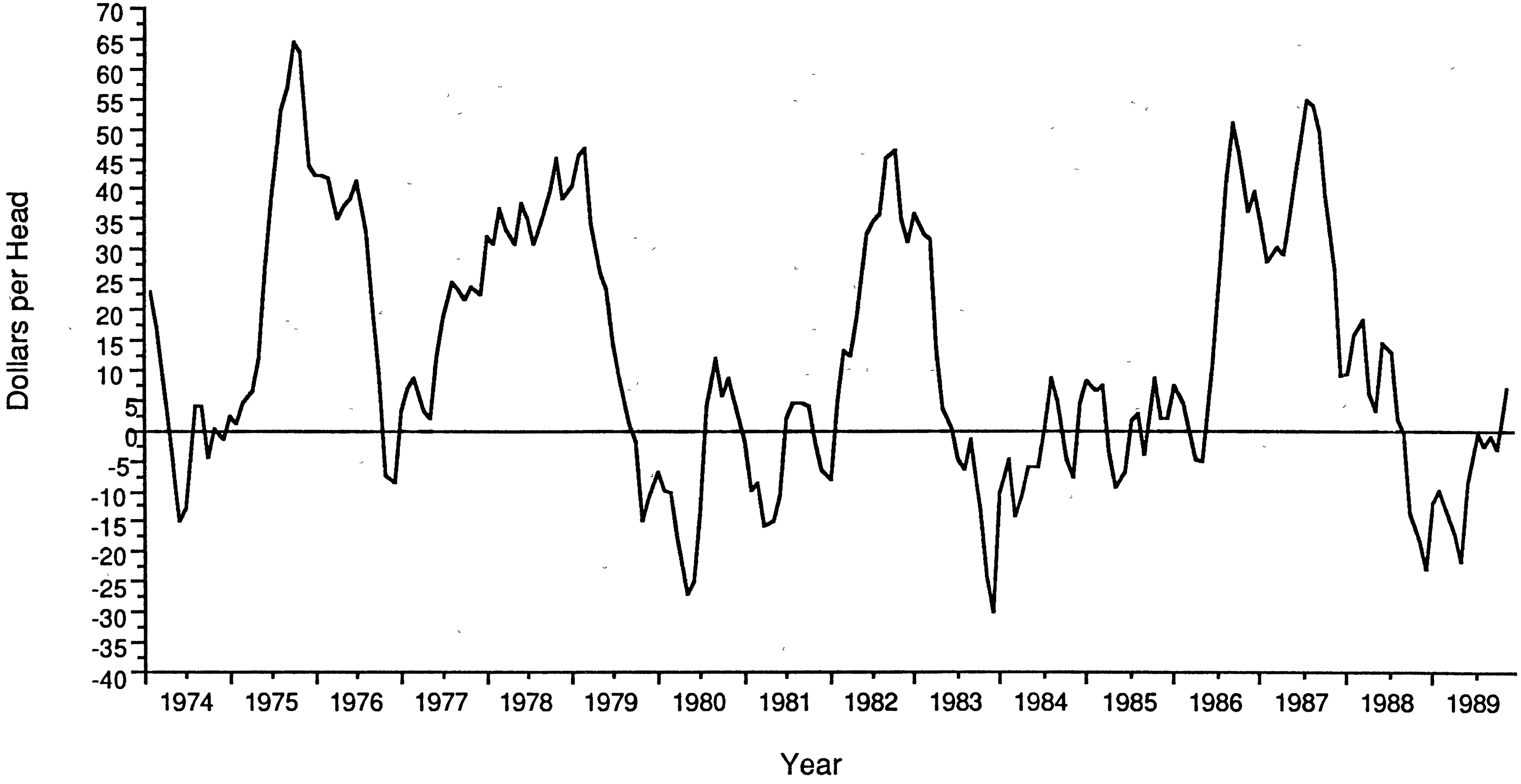


Figure 1. Estimated Profit From a Farrow-to-Finish Hog Operation in Iowa

and production cannot be known with certainty. The factors determining net income cannot be perfectly predicted.

Volatility has many ramifications in pork production. Resources will typically be inefficiently utilized. Producers might choose to operate at less than profit maximization levels. Some may be forced into bankruptcy.

Resources will be used inefficiently because producers, uncertain of either total output or prices for inputs and outputs, are unable to properly allocate their scarce resources. Furthermore, fixed resources such as buildings and equipment can not be modified to produce different products as quickly as factors change. Fixed resources constrain the flexibility of producers so that profit maximization becomes unachievable in every time period.

To protect against loss, producers may diversify or hedge their production. This results in less than profit maximizing levels of production.

The uncertainty associated with production and economic forces has had an effect on the number of producers who have gone out of business. This was most recently demonstrated by the farm financial crisis of the 1980's. Many producers expanded business operations with debt as profits rose in the 1970's. When producers laden with debt were confronted by the tighter economic conditions in the 1980's many were forced to liquidate their assets. What was perceived wise in one period turned out to be folly in another.

Producers, recognizing the volatility of prices and production, frequently make management decisions based on their prediction of what the parameter value may be. Many of these decisions prove to be erroneous. Much time and effort has gone into trying to control certain variables while others have been ignored in the study of volatility.

Hypothesis

The prices of inputs and outputs are a large determinant in net income and its associated volatility. But they are not the only determinants. Managers make decisions affecting output levels which, when aggregated, affect the price levels. The price cycle of hogs is a management induced phenomenon. Individual production decisions also influence net income and its variance.

The main hypothesis which this study addresses is: some breeding schemes and strategies are more utility-efficient than others currently available to commercial producers. A breeding scheme is defined as the use of a particular breed or crossbreed. A breeding strategy is defined as the management of a particular breeding scheme and addresses such things as managerial interference in farrowing and debt levels. Utility-efficient refers to maximizing net income while considering its variance and the risk attitudes of the producer.

The major emphasis regards management alternatives in production decisions and the impact of management alternatives on net income volatility. Market impacts on net income volatility are recognized but not emphasized.

The specific objectives are:

1. To determine superior production practices under uncertainty and estimate the cost of nonuse to producers with differing risk attitudes.
2. To quantify the amount of volatility attributable to selected production and marketing variables and the interrelationships of these variables.

Procedures

Two preliminary procedures are essential to address the above objectives. First, the pork production process is descriptively reviewed. Such aspects as technical coefficients and market prices are identified. This allows for the outlining of various breeding schemes and strategies and the recognition of various sources of volatility. Second, a firm level simulation model is modified to model pork production in a stochastic, dynamic framework.

Objective one is accomplished by simulating and studying various breeding schemes and management strategies. These schemes and strategies are ranked on their ability to generate income while considering variance of that income.

Objective two is accomplished by noting whole firm volatility and how it changes as several variables are assumed constant rather than stochastic. This procedure will be run only on the most and least efficient schemes.

Scope and Limitations

Management has the ability to change or modify many swine production practices. Production does not consist of a single input yielding a single output. Many factors interact to produce a combination of products.

The scope of this research is predominantly production oriented. Therefore marketing factors are included but not emphasized.

In quantitatively evaluating various management options, emphasis must be placed on the most critical variables within the scope of the study. The crucial variables looked at in this study reside in breeding schemes. Litter size and feed efficiency are used as the representative measures of breeds.

Several other traits such as litter weight, age to market, average daily gain and carcass quality have necessarily been omitted.

The data used in this analysis are obtained from experiments conducted in Oklahoma. Prices used are those which prevailed in Oklahoma during the study period. Reproductive efficiency and feed efficiency data are from research completed at the Oklahoma State University El Reno Experiment Station. These production standards may well represent others in the U.S. and have been published in national journals but are acknowledged as being Oklahoma specific. It is assumed that commercial producers could maintain the same management standards which were in place when the data were generated and therefore obtain similar production levels.

Existing production is assumed. No start up difficulties are modelled. The cost of changing from one management strategy to another is not addressed.

A confinement operation with dirt lot gestation is assumed. Production results may be different for pigs raised on dirt lots.

Dissertation Organization

Chapter II presents the economic, utility and statistical theory underlying the procedures used in this research. The theory of simulation is also presented.

Chapter III describes the simulation model (FLIPSIM V) and data used to perform the analysis. The swine breeding schemes and strategies are listed with their coefficients used in the analysis.

Chapter IV reports the results of simulating 27 breeding schemes and several management strategies. Volatility attributed to key production and marketing variables are reported in this chapter.

Chapter V summarizes the research, presents conclusions, and suggests further research.

CHAPTER II

THEORY

Introduction

Neoclassical production theory gives precise answers to the question of resource allocation among competing ends. Given the technical and price relationships between inputs and outputs, an optimal production plan can be obtained. Agriculture in general and pork production in particular would exhibit greater homogeneity than presently observed if this theory adequately modelled reality. Because the technical relationships and pertinent prices are unknown, pork production is characterized by diversity. Producers market hogs using different breeds, different facilities, different management styles.

Some of the differences in production schemes are attributable to resource constraints. Producers may use the production process attainable in order to maximize return on investment. Those limited in capital use labor intensive processes; those limited in time, technology intensive processes. Other differences cannot be considered a result of constraints. Such decisions as what breed of hog to raise and to which packer hogs are sold must be due to the perception of the producer. Producers choose to use different breeds because of perceived differences in them.

This difference in perception by producers points to the fact that answers to production decisions are not as precise as neoclassical production theory purports. The amount and type of input is not an exact science. Subjective and objective judgements come into importance as decisions are being made. The assumptions of the theory are limiting and can be relaxed to obtain more realistic and useful economic analysis.

This chapter summarizes neoclassical production theory: its assumptions and decision criteria. Problems of production under uncertainty are discussed. Specifically imperfect knowledge and time considerations are addressed. Utility maximization is discussed as an alternative to profit maximization. The utility function yields information regarding an individual's risk attitude which is combined with cumulative distribution functions of producer's after tax net present value to discuss stochastic dominance analysis. Statistical theory is briefly discussed as it pertains to the simulation procedures and sources of volatility. Lastly, pertinent theory regarding simulation, as utilized in this research, is presented.

Economic Theory

Neoclassical Assumptions

Beattie and Taylor list the assumptions of neoclassical production economics as:

1. timelessness or instantaneous production and nonperiodic production process where an activity has no relationship to the previous or subsequent activities;
2. all inputs and outputs are of homogeneous quality;
3. divisibility of factors and products where production is represented by a single, twice continuously differentiable production function;
4. perfect knowledge of the production function and all prices;
5. funds are not a limiting resource;
6. profit maximization is the objective function.

To these can be added the assumption of perfect competition in agriculture resulting in a producer being able to buy or sell any quantity of any commodity without affecting the price of those commodities.

The Production Function

Assumptions three and four above deal with the nature of the production function. Further understanding of the production function is critical. The following discussion assumes a single output, q, and one input, x. The theory can be expanded to accommodate m inputs and n outputs but is unnecessary at this time.

The production function is the technological relationship between output and input as indicated in equation 1.

$$q = f(x) \tag{1}$$

The production function is assumed twice continuously differentiable, allowing the first derivative of q with respect to x to be obtained. The resulting marginal product, MP, indicates the rate of transformation of x into q.

$$MP = \frac{\partial q}{\partial x} \tag{2}$$

The average product, AP, specifies the average amount of x required to produce a given level of q.

$$AP = \frac{q}{x} \tag{3}$$

Traditionally, the relationship between MP and AP delineates the three stages of production as illustrated in Figure 2. Stage 1 occurs when MP is greater than AP. Stage 2 occurs over the range of diminishing returns and is when AP is greater than MP and MP is greater than zero. The Law of Diminishing Returns states that if increasing amounts of input are added to the production process (ceteris paribus), the amount of output added per unit of

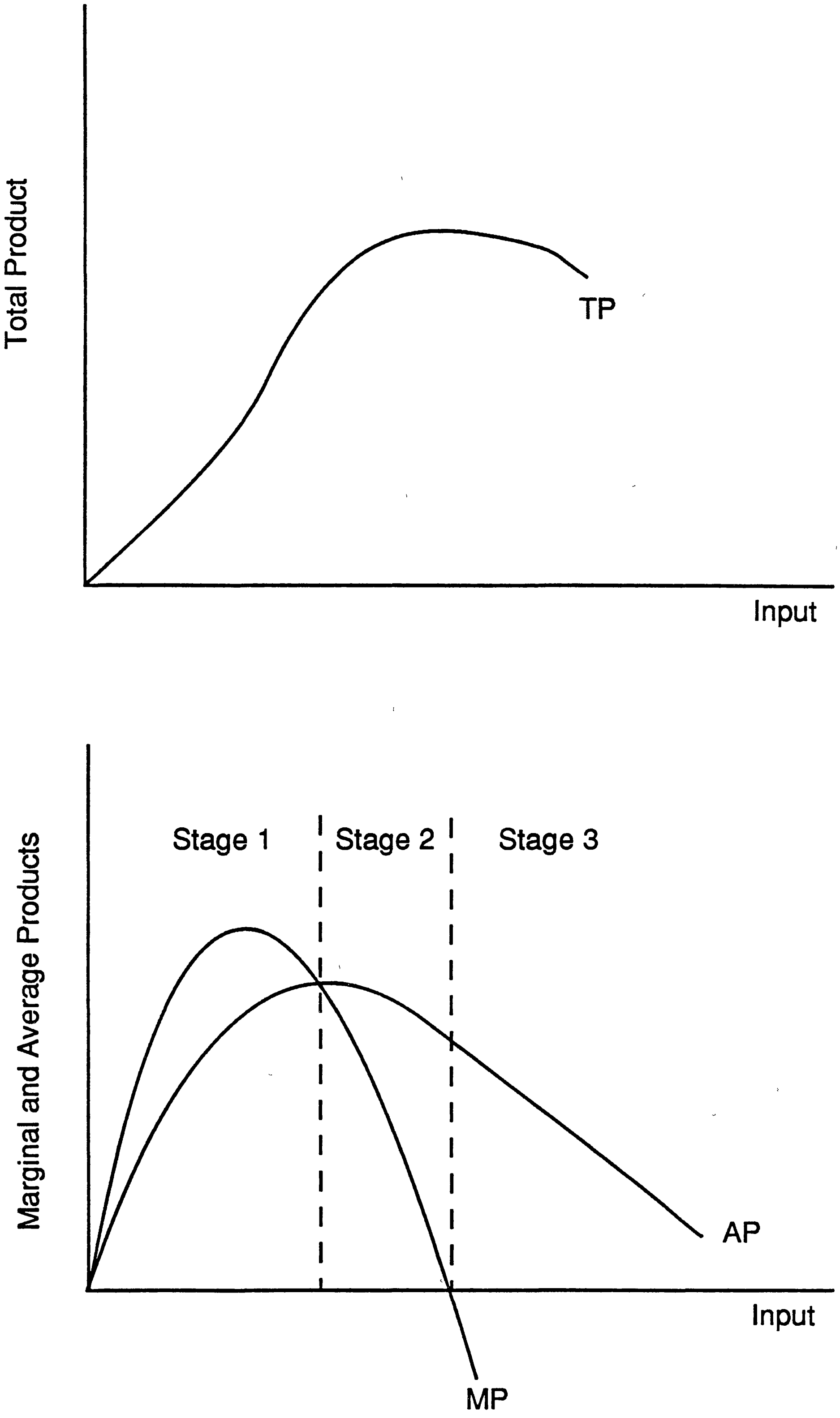


Figure 2. Classical Total Product, Marginal Product and Average Product Curves

input will eventually decrease. Stage 3 is when MP is less than zero. Stage 2 is the only justifiable region of production under the assumption of perfect divisibility of inputs. Stage 1 is unwise because the amount of output per unit of input is continuously increasing. Stage 3 is characterized by additional input causing negative output. The First and Second Order Conditions for production can now be specified by equations 4 and 5.

$$\text{First Order Condition: } MP = \frac{\partial q}{\partial x} \geq 0 \tag{4}$$

$$\text{Second Order Condition: } \frac{\partial MP}{\partial x} = \frac{\partial^2 q}{\partial x^2} \leq 0 \tag{5}$$

<u>Neoclassical Theory of the Firm</u>

Profit maximization is the assumed objective of the firm. Profit, Π, is defined as revenue minus costs and is written:

$$\Pi = pq - wx = pf(x) - wx \tag{6}$$

where: p = the price of the output q,

w = the price of the input x,

pq = the total revenue, TR, and

wx = the total cost, TC.

The first order condition for unconstrained profit maximization is

$$\frac{\partial \Pi}{\partial x} = p\frac{\partial q}{\partial x} - w = p\,MPP - w = VMP - w = 0 \tag{7}$$

so that

$$VMP = w \tag{8}$$

where VMP = the value of the marginal product.

The second order condition for profit maximization is

$$\frac{\partial^2 \Pi}{\partial x^2} < 0 \tag{9}$$

Solving for x completely determines the level of input which should be used and consequently the output produced and profit garnered.

There is a direct relationship between the production function and its product curves and the revenue/cost curves in the theory of the firm. Equation 6 shows the TR to be the product of q and p while equation 7 shows that VMP is the product of the MP and p. Graphically this represents a linear transformation in the TP and MP curves. Production occurs where the TR curve has the same slope as the TC curve; or identically, where the VMP curve intersects the cost of the input within the economically feasible region of stage 2 (Figure 3).

Production Under Uncertainty

Imperfect Knowledge If the assumption of perfect knowledge is relaxed, three new problems arise in the decision making process. First the production function is recognized not as a single twice continuously differentiable function but as the central tendency of collected data which exhibits not only a mean but a variance. In two dimensional space the production function might appear as in Figure 4 where the bars intersecting the TVP function represent a distribution about the mean through which the curve is estimated.

The second problem arises from the first. Profit maximization is an optimization problem applied to a mean. The optimal input level will change depending on whether the TC curve is tangent to the fitted production function (output level x') or to the maximum of each distribution (output level x").

The third problem occurs because imperfect knowledge deals not only with the production function but also with prices. When prices are known imperfectly, the slope of the price line is indeterminate so that even if the production function were certain, a point of tangency could not be specified.

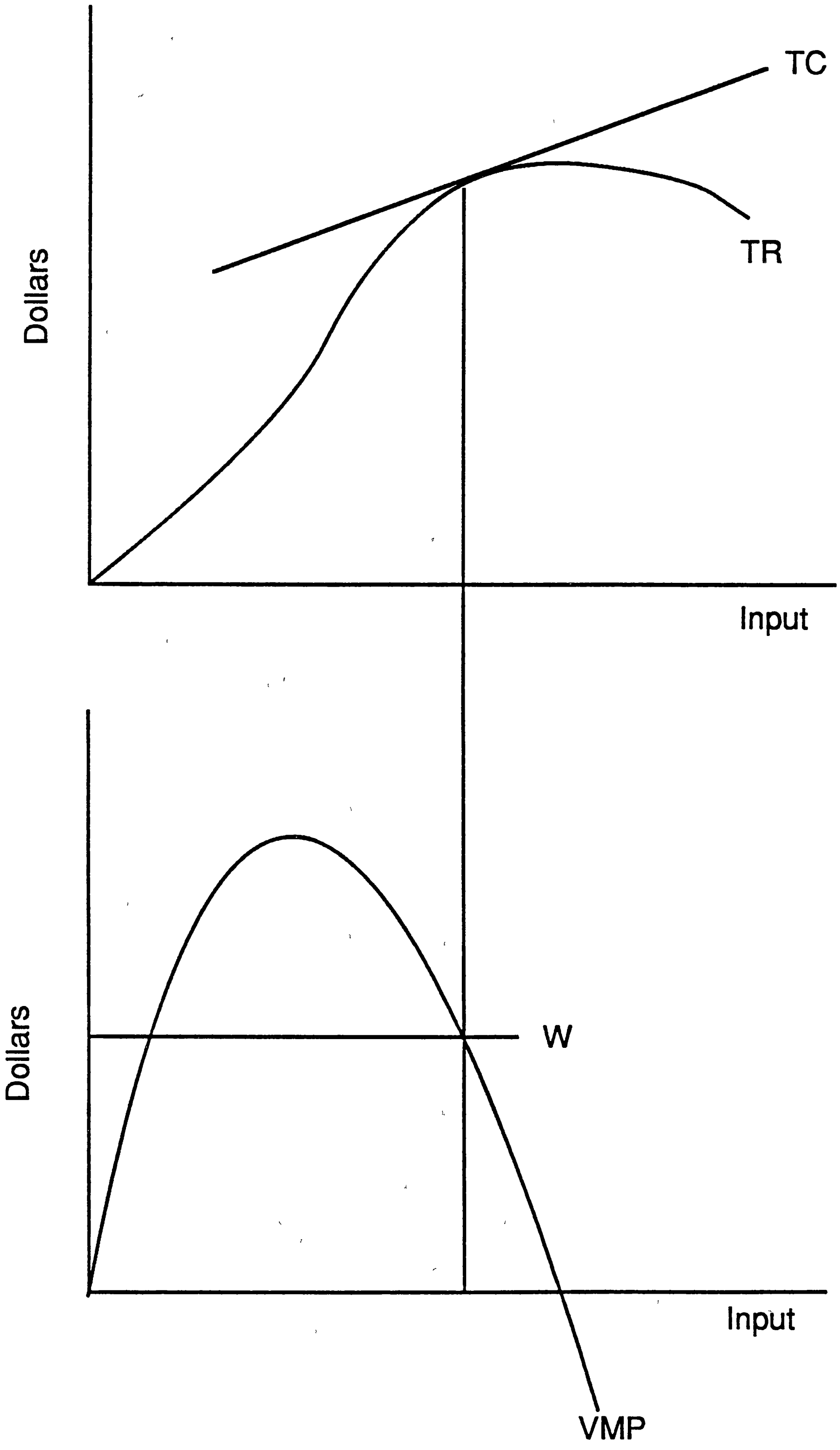


Figure 3. Total Cash, Total Value Product & Value of the Marginal Product Curves

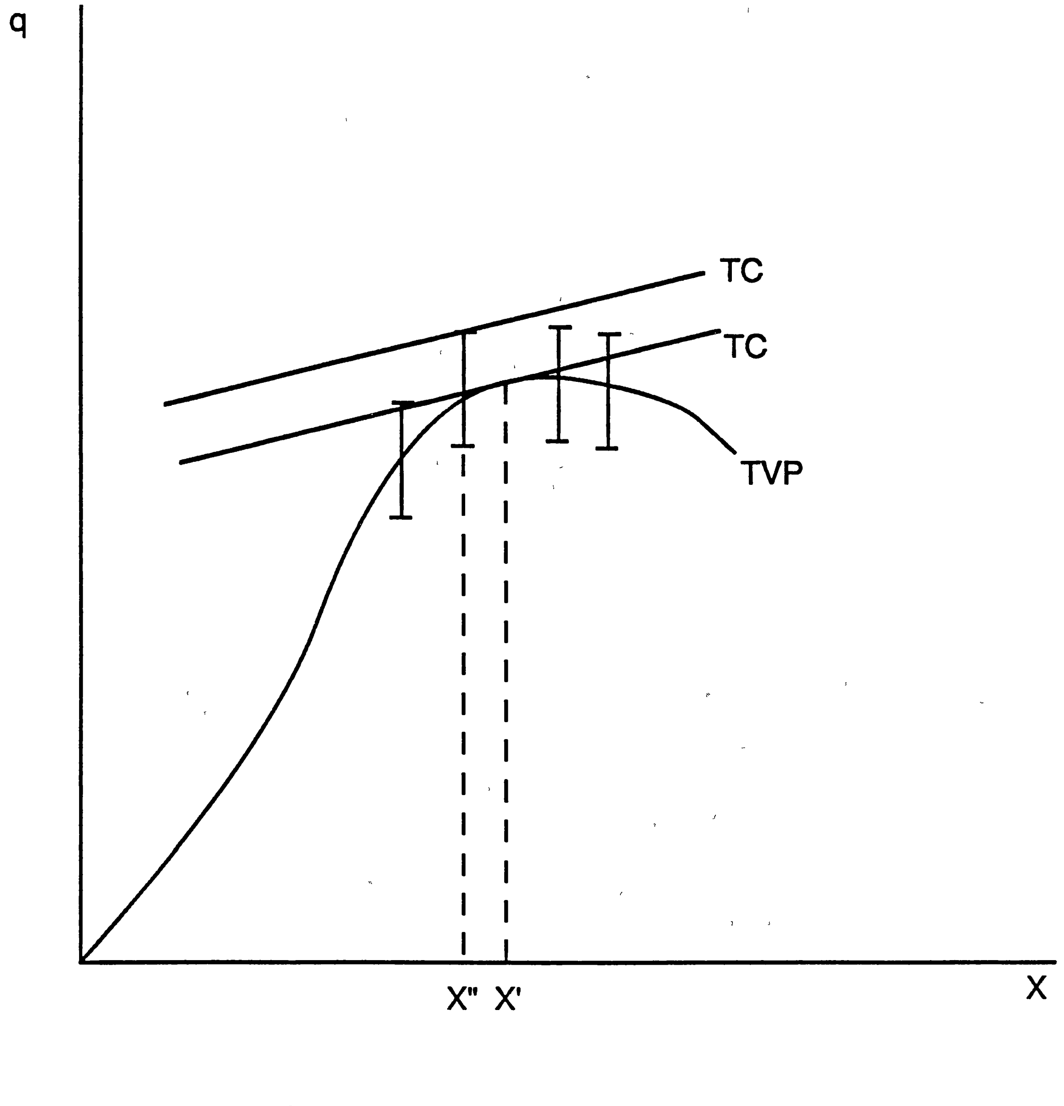


Figure 4. Production Under Uncertainty

Imperfect knowledge in either prices or production causes uncertainty. The end result is that profit maximization no longer becomes an acceptable objective function. Utility maximization, discussed in a later section, offers one means of dealing with uncertainty.

Time Considerations Two aspects of time impact the optimal production plan. The first deals with the dynamic nature of production where one outcome affects later outcomes. The second deals with the time value of money.

When considering production as a dynamic process where one outcome affects another, results may vary from the static analysis. For the production of pork, the reproductive efficiency of different breeding schemes will affect the number of pigs raised. This, in turn, will affect the whole herd feed efficiency as the feed required to maintain the breeding herd is spread over more (fewer) market animals. Feeding efficiency also impacts the economic analysis through the marketing, or purchase, of feedstuffs. As feeding efficiency rises (falls), less (more) feed is required and bought. Less (more) operating capital is required and the opportunity cost of that expense decreases (increases). The average fixed costs associated with a market hog will also vary as more (fewer) pigs utilize the facilities in place.

Though fixed costs are not considered variable by definition, the way in which a producer transforms flow resources to stock resources does make them variable to a certain degree. Policies such as tax law and farm programs affect the conversion of flow to stock decisions and since policies change, fixed costs do have a measure of volatility associated with them. In the early years of a major asset purchase, depreciation expense will most likely be recorded greater than actually warranted. After several years the asset may be fully depreciated but still contribute to output. This implies that in the early years, paper profits are less volatile and less volatile than actual profits since a larger part of total cost is composed of fixed costs and therefore volatility of total costs is decreased.

The time value of money becomes a critical component of any analysis involving more that one time period. A dollar today is considered more valuable than a dollar one year from now. The difference in value is a function of the other opportunities for that money. Several methods have been devised to account for the time value of money. The Net Present Value (NPV) Approach discounts all money to the present value through use of a discount rate, r:

$$NPV = \sum_{i=1}^{n} \frac{NW_i - NW_{i-1}}{(1 + r)^i} \qquad (10)$$

where: NW_i = the net worth in period i and

n = the number of time periods.

The shortcoming of this approach is that of choosing a discount rate. Theoretically the value chosen should reflect the rate of return obtainable by the next best investment. This is not always an easy choice since frequently the purpose of the analysis is to rank investments.

An alternate method is the Internal Rate of Return (IRR) method. This method consists of setting the NPV equation equal to zero and solving for the discount rate. The solution requires an iterative process and is best accomplished using a calculator or computer package. The decision process reduces to choosing the investment with the highest IRR. The IRR method works well when all the alternatives being considered have lives of equal length.

For the purpose of ranking the various breeding schemes, the NPV method is employed with every scheme using the same discount rate. The IRR method yields the same result since all of the schemes have lives of equal length. The NPV method is used because the computer algorithm for its use in stochastic dominance analysis already exists.

Decision Criteria

In the ranking of alternative farm plans over time and under uncertainty, much debate has occurred over the best decision criterion. The coefficient of variation, CV, is an appropriate measure of variance when discussing more than one alternative. "The CV shows the risk per unit of return and it provides a more meaningful basis for comparison when expected returns on two alternatives are not the same (Brigham and Gapenski, p.177)." Higher CVs indicate "greater relative dispersion of outcomes around the expected value. Thus, the likelihood of loss may be greater. The choice between . . . two investments depends on the manager's risk-return preference (Barry, et al.)." CV is determined using

$$CV = \frac{\sigma}{\mu}(100). \tag{11}$$

where: σ = the standard deviation and

μ = the mean.

Portfolio analysis recognizes that in the presence of risk, producers will choose among alternative plans based on both expected income and its associated variance. A producer will choose a more risky plan (defined as having a higher variance) only if the expected income rises sufficiently to compensate for the increased risk. Rationally, only those plans in which the associated income variance is minimized for a given income level will be feasible. Empirical studies bear out the hypothesis that producers sacrifice some income for a reduced level of risk (Dillon and Scandizzo, Moscardi and deJanvry).

Together the time dimension and imperfect knowledge confute the assumption of profit maximization. If indeed a producer had certain knowledge, profit maximization would be sought. But since uncertainty causes risk, and frequently profit maximization entails maximum risk, profit maximization may not be the true objective function. Also one investment may offer more profit over time than another but that profit comes too late in the time horizon to satisfy the producer's preferences. Under these conditions, utility maximization becomes an acceptable and necessary alternative.

Utility Theory

Utility theory is based upon four axioms regarding preferences. They are:

1. Ordering: for two alternatives, X and Y, either X is preferred to Y or Y is preferred to X or neither (indifference.).
2. Transitivity: for three alternatives, X, Y and Z, if X is preferred to Y and Y is preferred to Z, then X is preferred to Z.
3. Continuity: if X is preferred to Y and Y is preferred to Z then some probability exists which will make a decision maker indifferent between alternative Y for certain and a gamble of receiving X with probability p and receiving Z with probability 1-p.
4. Independence: if X is preferred to Y, and Z is another choice, then a risky choice consisting of $p(X) + (1-p)(Z)$ is preferred to $p(Y) + (1-p)(Z)$ (Varian).

In a risky situation, the decision maker must choose between alternative courses of action whose outcomes are determined by the state of an uncertain environment. Letting a_j = the jth act or alternative course of action; s_i = the ith state of the environment; $p_i = P(s_i)$ = the probability that s_i occurs; and x_{ij} = the outcome of a_j given that s_i occurs, the expected utility hypothesis is based on preferences that are consistent with the axioms of ordering, transitivity, continuity, and independence, for which there exists a utility function, U(.), such that : a) if any risky action, a_1, is preferred to another, a_2, then $U(a_1) > U(a_2)$, and b) $U(a_j) = E_iU(x_{ij}) = \sum_i p_iU(x_{ij})$. The optimal act, a_j^*, is that which maximizes expected utility (Bailey and Boisvert):

$$U(a_j^*) = \text{Max } U(a_j) = \text{Max } [\sum_i p_iU(x_{ij})]. \tag{12}$$

The utility function is taken to be a single valued function of some measure of wealth, x.

Additional restrictions which can be assumed on the utility function are given next. 1) The individual prefers more to less. The utility function will be monotonically increasing under this assumption and its derivative with respect to x will be greater than zero. 2) The individual is risk averse. The utility function then exhibits decreasing marginal utility of wealth and the second derivative with respect to x is less than zero.

The utility function is not a unique representation of preferences. The only relevant feature of a utility function is its ordinal character of describing preferences. Any strictly increasing transformation of the utility function, f(U(x)), will represent exactly the same preferences since f(U(x)) > f(U(y)) if and only if U(x) > U(y) (Varian).

Risk attitudes can not be adequately ascertained from the utility function. The second derivative of U(x) may give an indication of risk aversity but it is not invariant under linear transformations. Risk attitudes are best represented by the Arrow-Pratt absolute risk aversion coefficient:

$$r_a(x) = -\frac{U''(x)}{U'(x)} \tag{13}$$

where $U'(x)$ = the first derivative of U with respect to x and

$U''(x)$ = the second derivative of U with respect to x.

This coefficient gives a measure of risk attitude at a particular level of wealth, is a unique measure of preferences and is unchanged by any positive linear transformation of U(x).

Utility provides the framework for risk analysis by providing the theoretical basis of the risk aversion coefficient. This research does not utilize a utility function, as such, but makes extensive use of the risk aversion coefficient. Ideally, this coefficient would be elicited from each individual for whom a ranking of alternatives is desired. However the elicitation procedures are costly and, at present, imprecise. The risk attitude of a group of individuals may be sufficient when the outcome under study affects a group rather than an individual. Thus a partial ordering of outcomes can be obtained by specifying two subsets: 1) the efficient set and 2) the inefficient set.

The efficient set is defined as that set of alternatives which contains the preferred choice for every individual whose preferences conform to the restrictions. Alternative 1 is preferred to alternative 2 if $E_1(U) \geq E_2(U)$ for every utility function in the defined set. The inefficient set is then the set which contains alternatives which no individuals described by the restrictions would prefer.

The simplest approach to efficiency analysis is the mean-variance, or the EV, rule. Alternative 1 is preferred to alternative 2 if $E(x_1) \geq E(x_2)$ and $V(x_1) \leq V(x_2)$ with at least one being a strict inequality. It assumes that variance is an adequate measure of risk and that the second moment about the mean is sufficient to describe the outcome of the alternatives (i.e. skewness and kurtosis are absent or unimportant). Variance is not an adequate measure of risk because it assumes that extreme positive values are as undesirable as extreme negative values. Also, assuming normality in the distribution of alternatives may give misleading results.

The theory of stochastic dominance gives alternative efficiency criteria. The preferred choice is that stochastically dominants others. The stochastic dominance criteria allows the ranking of alternatives, according to expected utility maximization, for a specified set of utility functions.

First degree stochastic dominance (FSD) is the least restrictive of the criteria. It is appropriate for decision makers who possess a monotonically increasing utility function or who prefer more income to less income. In terms of the risk aversion coefficient, $-\infty < r_a < +\infty$. Let F and G represent two risky alternatives over the relevant range [a,b] and let them be described by the probability density functions (pdf's) f(x) and g(x), respectively. The cdf's for each of these are defined:

$$F_1(X) = \int_a^b f(x)\ dx \tag{14}$$

and

$$G_1(X) = \int_a^b g(x)\ dx, \tag{15}$$

where the subscript "1" denotes that the pdf has been integrated once. Alternative F dominates alternative G by FSD if $F_1(x) \leq G_1(x)$ for all x over the range [a,b] with at least one strict inequality. Graphically, this occurs when $F_1(X)$ lies nowhere to the left of $G_1(X)$. In Figure 5, C dominates A and B since C lies nowhere to the left of either A or B. A and B cannot be ordered using FSD because they cross. The weakness of FSD is that it eliminates few options from the efficient set and the decision maker is still confronted with a large set of alternatives.

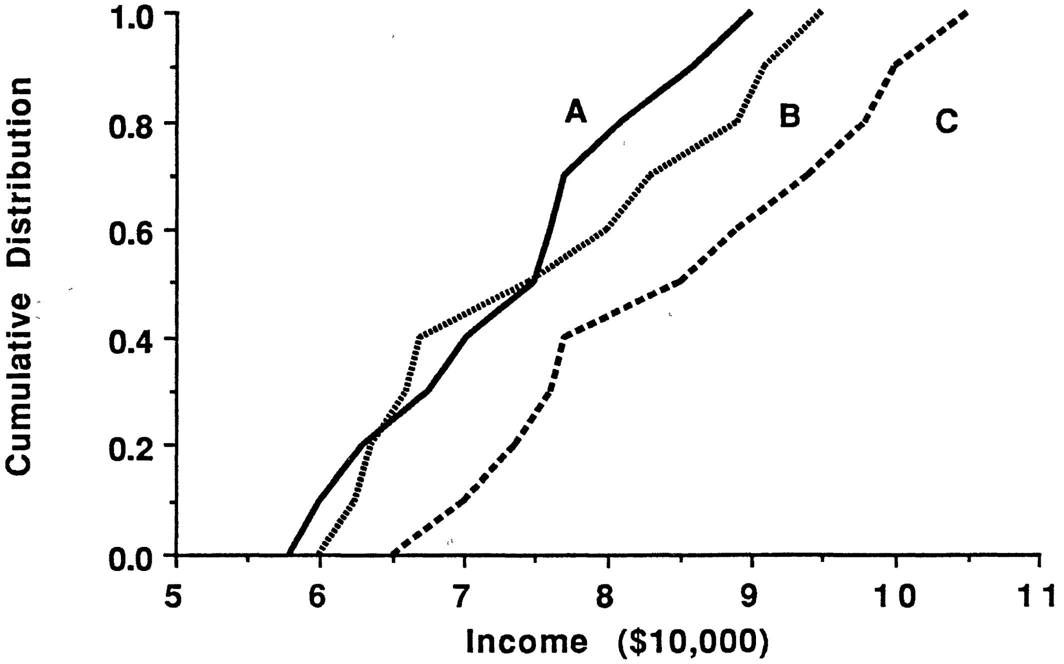


Figure 5. First Degree Stochastic Dominance

Second degree stochastic dominance (SSD) narrows the efficient set more than FSD by making the assumption that the decision maker is risk averse. Hence, the second derivative of U(x) with respect to x is less than zero causing the risk aversion coefficient to lie between zero and positive infinity. The SSD criterion requires an assessment of the differences in the area between $F_1(X)$ and $G_1(X)$ over the range [a,b]. Let

$$F_2(X) = \int_a^b F_1(x)\,dx \tag{16}$$

and

$$G_2(X) = \int_a^b G_1(x)\,dx. \tag{17}$$

F dominates G if $F_2(x) \leq G_2(x)$ for all x in [a,b] with at least one strict inequality. Graphically, SSD is interpreted as F is preferred to G, by all decision makers who are risk averse if, and only if, the area under F(X) is less than the area under G(X) (Figure 6 top). When the cdf's cross, the area between F(X) and G(X) when F(X) lies above G(X) must be less than the area between them when F(X) lies below G(X). Alternative B dominates A because the integral of B lies nowhere to the left of the integral of A (Figure 6 bottom). If a person's absolute risk aversion coefficient is positive, then an option whose minimum value is less than another's would never be preferred - regardless of the area under the two curves. This is an infrequent occurrence but is noted here for clarification. True SSD requires the dominant strategy to have the largest minimum.

For narrowing the efficient set beyond FSD and SSD, Generalized Stochastic Dominance (GSD) offers the most discrimination and flexibility. GSD, developed by Meyer, is a criterion which orders uncertain choices for decision makers whose absolute risk aversion functions lie within specified upper and lower bounds $r_{a1}(x)$ and $r_{a2}(x)$. The interval can be as wide or as

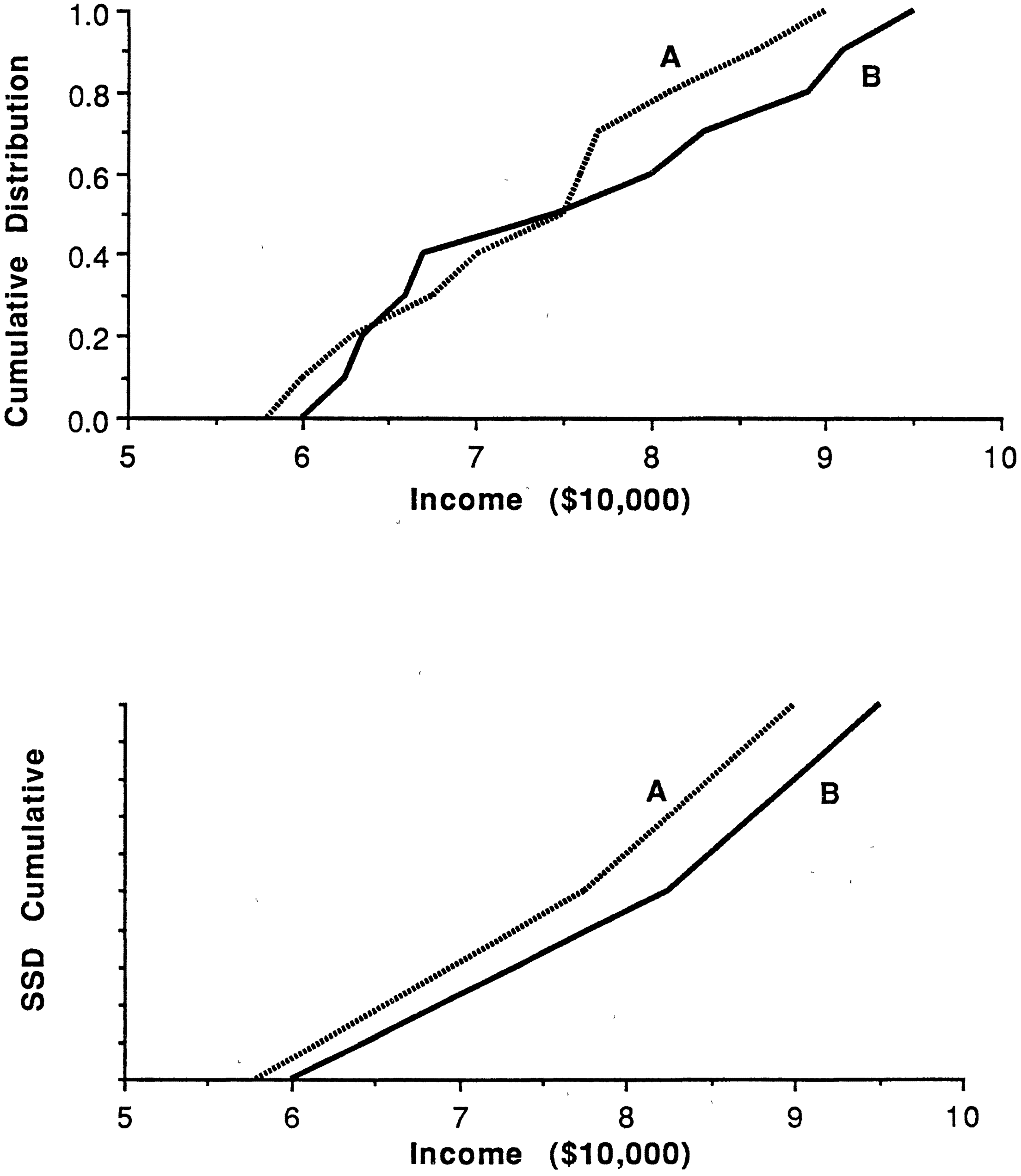


Figure 6. Second Degree Stochastic Dominance

narrow as desired where intervals of -∞ and +∞ would yield the same ordering as FSD and intervals of 0 and +∞ would yield the same ordering as SSD.

The solution procedure requires the identification of a utility function U(x), which minimizes:

$$\int_{-\infty}^{\infty} [G(x) - F(x)]\, U'(x)\, dx \qquad (18)$$

subject to the constraint

$$r_{a1}(x) \leq -\frac{U''(x)}{U'(x)} \leq r_{a2}(x) \qquad (19)$$

for all values of x.

Expression (18) accounts for the difference between the expected utilities of F(x) and G(x). If, for the decision makers defined by the absolute risk aversion bounds, the minimum of this difference is positive, then F(x) is preferred to G(x). This implies that the expected utility of F(x) is always greater than that of G(x). If the minimum is zero, the alternatives cannot be ranked; the choice is indeterminant. If the minimum is negative, the solution requires the identification of a utility function which minimizes

$$\int_{-\infty}^{\infty} [F(x) - G(x)]\, U'(x)\, dx \qquad (20)$$

subject to the same constraint in equation (19).

A complete ordering is not guaranteed using GSD because the minimum of both (23) and (25) can be negative, which implies that neither distribution is unanimously preferred by the relevant group of decision makers.

The algorithms used in stochastic dominance analysis are also useful in approximating the value of information. Mjelde and Cochran show that a producer's willingness to pay for information can be thought of as a premium which equals the amount which can be charged in each state of nature before the producer is indifferent to buying the information. Two cdf's are generated.

One cdf (F(X)) uses decisions obtained while utilizing the information; the other cdf (G(C)) uses decisions obtained without utilizing the information. The lower bound on the information is the minimum value of the premium, π, such that F(x - π) no longer dominates G(X). The upper bound on the information is minimum premium such that G(X) dominates F(x - π). Mathematically the lower bound is given by:

$$\min \pi \text{ such that } EU(F(x - \pi)) - EU(G(x)) \leq 0 \text{ for at least one } U \text{ in } \zeta. \tag{21}$$

where ζ is the admissible class of utility functions.

The upper bound differs in that a strict inequality holds for all decision makers defined by ζ.

This research utilizes the same equations (hence, algorithm) to arrive at a different concept - the cost of adoption. The premium corresponds to the present value cost entailed when moving from one scheme (G(X)) to another scheme which is stochastically dominant (F(X)). If the cost of adoption is less than the lower bound given by the algorithm, every producer conforming to the risk restrictions will opt to move from scheme G to scheme F. If the cost of adoption is equal to the lower bound, at least one producer will choose to continue operating with the inefficient scheme, G. If the cost of adoption is greater than or equal to the upper bound, no producer will want to change production practices.

Statistical Theory

Probability

The value of a stochastic simulation model rests heavily on the probability values used as input. Probabilities quantify the chance that a given event will occur. Often the probabilities assigned to events are based on a record of how frequently the event has occurred in the past. Anderson et al. state that this objective approach assumes that "the historical structure is unchanged and is relevant to the specific planning period under review . . . .such objective relative frequencies as probabilities in decision analysis is a mechanical, a simplistic and probably an inefficient and inaccurate procedure of specification." They propose that subjective probability, defined as the strength of conviction an individual has about a proposition, is the only valid concept in decision making. Indeed, they state that "'objectivity' in science is a myth, in life an impossibility, and in decision making an irrelevance" (Anderson et al., pp. 17,18).

This thesis makes use of both "objective" and subjective probabilities. In any work which seeks to make a generalized decision applicable to many producers, some objective probability must be used. In the case of prices, probabilities are simplistically assumed dependent on historical frequencies. The price covariance matrix is merely the result of the historical occurrences. It is not totally objective in that the prices are detrended to account for the inflationary period of the 1970's. The subjective assumption in effect when doing this is that the inflation of the 1970's was abnormal and unduly influenced the variation attributable to chance. Yet it is not totally subjective in that the values do not represent the strength of conviction of any one individual.

The purest form of objective probabilities used in this study is the descriptive statistics associated with the number of pigs weaned and feed efficiency inherent in various breeding schemes. These are used as reported by animal scientists with no modifications.

The purest form of subjective probabilities also involves the descriptive statistics associated with reproductive efficiency of some of the breeding schemes which are later chosen for further analysis. In this case, the assumption of normality is dropped in favor of the assumption of a triangular distribution. The triangular distribution is solely the subjective probability imposed by this researcher. It is thought to better represent the impact of management on the number of pigs weaned.

Descriptive Statistics

For continuous random variables the cumulative distribution function (cdf) gives the probability that an observed value will be less than or equal to a specified value. The cdf is denoted as

$$F_X(t) = P(X \leq t) \qquad (22).$$

If the specified value, t, is the maximum attainable value for that particular function then $F_X(t) = 1$; if it is the minimum attainable value, $F_X(t) = 0$. The density function, $f_X(x)$,of a variable is the derivative of the cdf. Most of the simulations in this study assume a normal distribution. Their density function and cdf are specified as

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} * \exp(- \frac{(x - \mu)^2}{2\sigma^2}) \qquad \text{for } -\infty < x < \infty, \qquad (23)$$

and

$$F(t) = \int_{-\infty}^{t} \frac{1}{\sigma * \sqrt{2\pi}} * \exp(- \frac{(x - \mu)^2}{2\sigma^2}) \, dx, \qquad (24)$$

respectively,

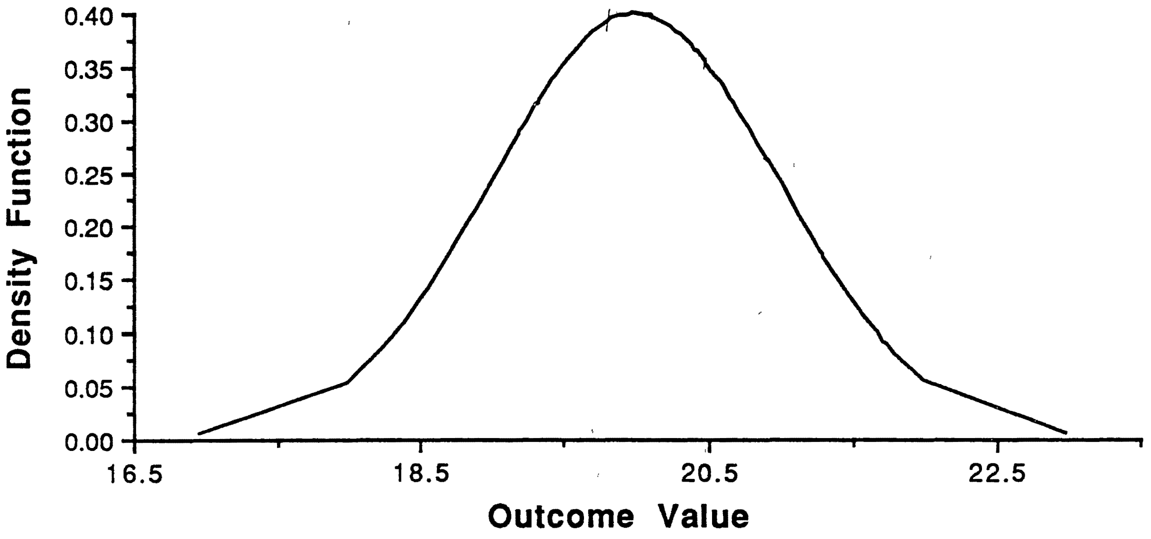
where: μ = the mean of the distribution,

σ = the standard deviation of the distribution,

x = the observed value of the variable and

exp = the natural logarithm.

The normal density and cdf are illustrated in Figure 7.



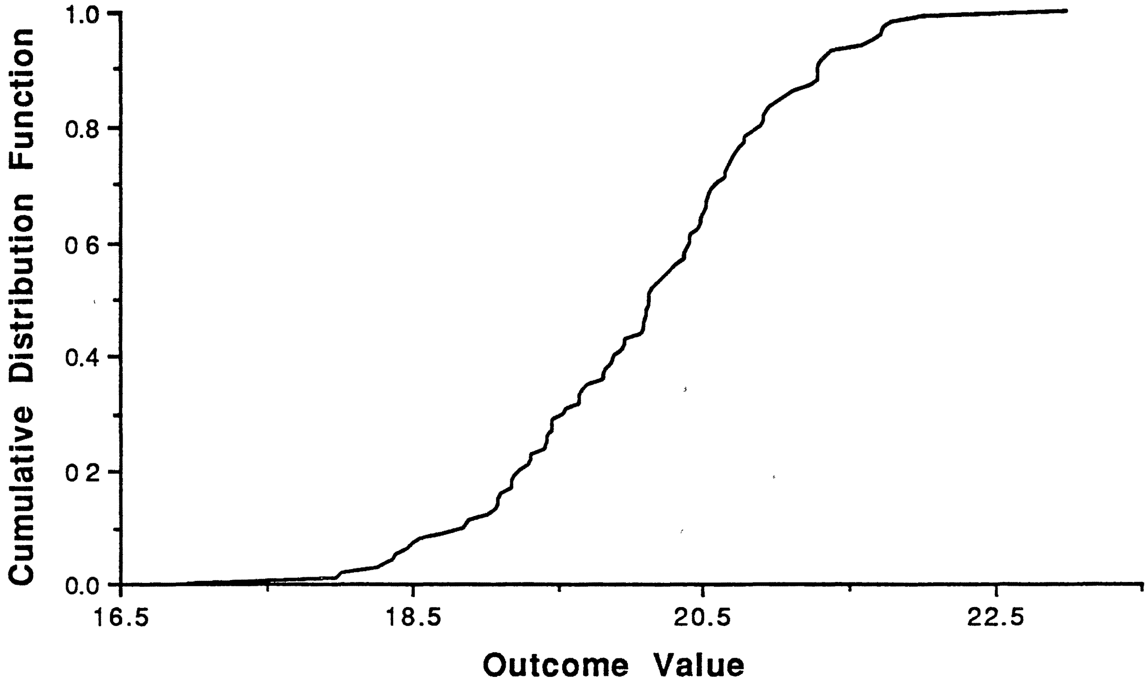


Figure 7. Normal Density and Cumulative Distribution Functions

The triangular distribution is assumed in some of the simulations. Their density function and cdf are given as

$$
\begin{aligned}
f(x) &= \frac{2\,(x - a)}{(b - a)(m - a)} && \text{for } a \leq x \leq m \\
&= \frac{2\,(b - x)}{(b - a)(b - m)} && \text{for } m \leq x < b \\
&= 0 && \text{for all other values of } x. && (25)
\end{aligned}
$$

$$
\begin{aligned}
F(x) &= 0 && \text{for } x < 0 \\
&= \frac{(x - a)^2}{(b - a)(m - a)} && \text{for } a \leq x \leq m \\
&= 1 - \frac{(b - x)^2}{(b - a)(b - m)}) && \text{for } m \leq x < b \\
&= 1 && \text{for } x \geq b, && (26)
\end{aligned}
$$

respectively,

where a = the minimum value

b = the maximum value and

m = the mode.

Figure 8 illustrates these two functions.

The most familiar statistic is the mean. Technically, the mean is the expected value of x, E(x), and is defined as the first moment about the origin of the uncertain quantity. For continuous variables,

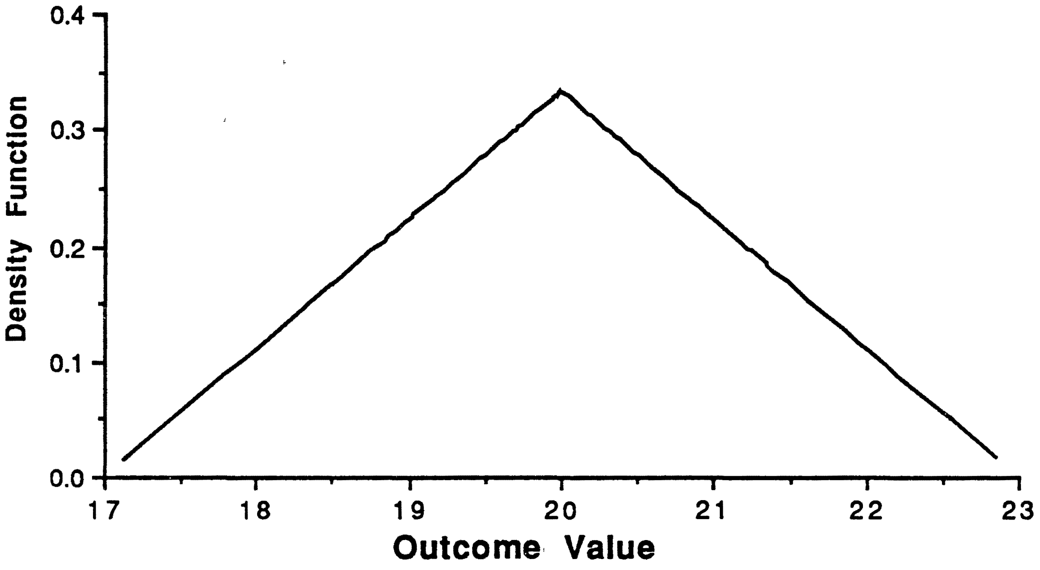
$$E(x) = \int_{-\infty}^{\infty} x\, f(x)\, dx \qquad (27)$$

where f(x) = the probability density function.

Empirically, the mean is estimated by the equation

$$E(\hat{x}) = \frac{\sum_i X_i}{n}\,. \qquad (28)$$

It is distinguished from the mode which is defined as the value of x occurring with the most frequency. The mean equals the mode for all symmetric



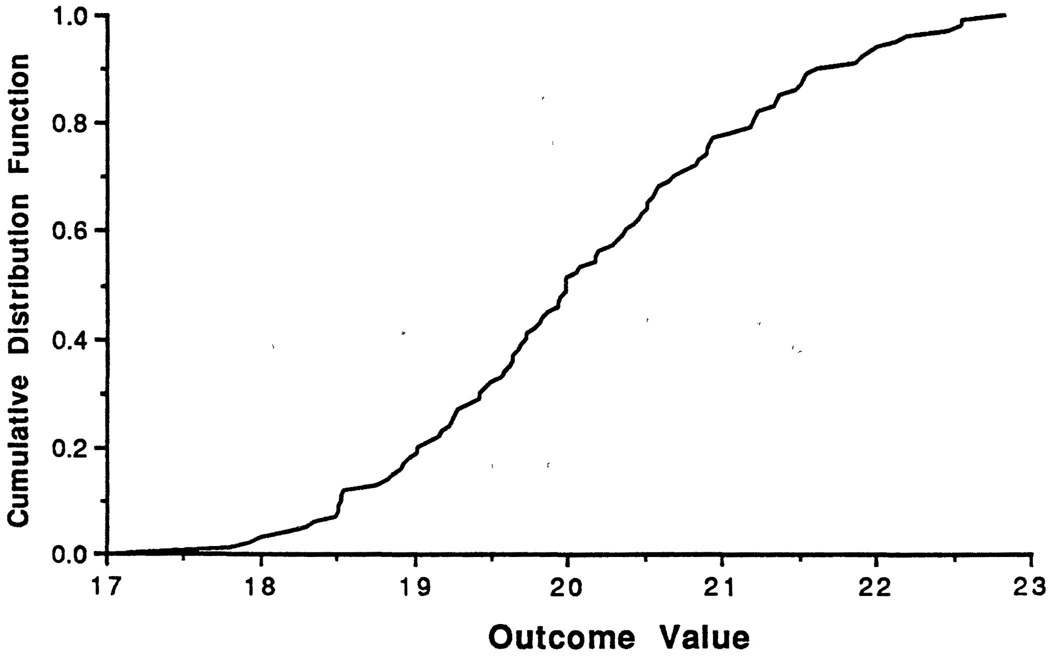


Figure 8. Triangular Density and Cumulative Distribution Functions

distributions such as the normal and triangular with $m = \frac{a = b}{2}$. In the triangular distribution the mean is typically less than the mode for distributions which are skewed to the left; greater than the mode for those which are skewed to the right.

The variance of a population, V(x), is the second moment about the mean:

$$V(x) = E[x-E(x)]^2 = \int_{-\infty}^{\infty} [x-E(x)]^2 \, f(x) \, dx \qquad \text{for a continuous function.} \quad (29)$$

The standard deviation is simply the square root of the variance. The standard error is used when describing the variance associated with means. The variance among means of individuals is less than the variance among individuals. The relationship is

$$\text{s.e.} = \sqrt{\frac{V(\bar{x})}{n}} \qquad (30)$$

where $V(\bar{x})$ = the variance of the population of means, $\bar{x}$, obtained by sampling the parent population of individuals with variance, V(x). The standard error is the correct measure of dispersion for simulating the average number of pigs weaned and the feed efficiency for a swine enterprise.

The range of a normally distributed random variable is theoretically negative infinity to positive infinity. However, 99.7 percent of the observations are expected to lie within the range of plus or minus three standard deviations. Intuitively, negative values for some variables are unrealistic. The number of pigs weaned cannot be less than zero. If market prices were less than zero, producers would pay people to take animals rather than market them. For simulation purposes the minimum of every distribution has been set at zero. The range of a triangularly distributed random variable is determined by the decision maker when the minimum and maximum values are specified.

Skewness is a measure of how asymmetric a distribution is. It is the third moment about the mean. A normal distribution exhibits no skewness since it has no odd moments higher than the first. The triangular distribution is skewed to the left (right) if the minimum (maximum) value is further from the mode than the maximum (minimum) value. Agricultural income frequently exhibits positive skewness (Kramer and Pope). Skewness is considered in stochastic dominance analysis. Mean-variance analysis assumes there is no skewness. Hence, if the results of simulation indicate skewness, the mean-variance analysis is theoretically invalid.

The covariance of two random variables, x_1 and x_2, is used as a measure of how two random variables vary together. Unlike the variance of a random variable which must always be positive, the covariance can be negative, zero, or positive. If negative, x_1 and x_2 tend to move in opposite directions; if positive, in like directions. The covariance is important when simulating two variables thought to be correlated.

The correlation between two variables is measured by the equation

$$\rho = \frac{C(x_1,x_2)}{\sqrt{(V(x_1)\ V(x_2))}} \ . \qquad (31)$$

The correlation can be any number between -1 and +1. Negative one indicates a perfect negative correlation between the two variables so that when one moves up the other moves down. A perfect positive correlation of +1 occurs when the two variables move together the same relative amount.

Theory Regarding Variance Analysis

Part of this thesis seeks to distinguish the impact of individual random variables on the total variance associated with a pork producer's income. Statistical theorems critical to this endeavor are listed below without proofs.

1. If $(X_1, X_2, \ldots, X_n)$ are random variables and

   if $Y = \sum_{i=1}^{n} a_i X_i$

   then $E(Y) = \sum_{i=1}^{n} a_i \, E(X_i)$ and

$$V(Y) = \sum_{i=1}^{n} a_i^2 \, V(X_i) + 2 \sum_{i \neq} \sum_{j} a_i \, a_j \, C(X_i, X_j)$$

   where: $E(X_i)$ is the expected value of X_i

   $V(X_i)$ is the variance of X_i and

   $C(X_i, X_j)$ is the covariance between X_i and X_j.

2. If X_1 and X_2 are random variables and

   if $Y = X_1 * X_2$

   then $E(Y) = E(X_1) \, E(X_2) + C(X_i, X_j)$

   $V(Y) \approx E^2(X_1)V(X_2) + E^2(X_2)V(x_1) + 2\, E(X_1)E(X_2)C(X_1, X_2)$ when X_1 and X_2 are correlated;

   $V(Y) = E^2(X_1)V(X_2) + E^2(X_2)V(x_1) + V(X_1)V(X_2)$ when X_1 and X_2 are statistically independent (Goodman).

3. If $(X_1, X_2, \ldots, X_n)$ are uncorrelated random variables and

   if $U = \sum_{i=1}^{n} a_i X_i$ and $Z = \sum_{i=1}^{n} b_i X_i$

   then the covariance between U and V is $C(U,Z) = \sum_{i=1}^{n} a_i \, b_i \, V(X_i)$ (Bohrnstedt and Goldberger).

Simulation

Models are frequently utilized to aid in the study of various economic systems. Some critical theory regarding proper model building is presented in this section as it pertains to the model used in this research.

A model is "a system of postulates, data and inferences presented as a mathematical description of an entity or state of affairs (Websters)." Model complexity ranges from extremely simple one input, one output production functions to extremely complex systems of equations which require computers for operation.

Naylor defines simulation as a numerical technique for conducting experiments with certain types of mathematical models which describe the behavior of a complex system on a digital computer over extended periods of time. Law and Kelton add that, in simulation data are gathered to estimate the desired true characteristics of the model. With simulation, an experiment is conducted with a model of the real system rather than with the actual system itself.

Simulation models can be either static or dynamic and either deterministic or stochastic. A static model represents a system at a point in time while a dynamic model represents a system as it evolves through time. Deterministic models contain no random variables. Stochastic models accommodate one or more random variables. The random variables can be modelled as either discrete or continuous, depending on the distribution warranted by the data. Discussion in this section will be limited to stochastic, continuous and dynamic simulation because FLIPSIM V, the model used in this research, is such a model.

To utilize simulation, the system under study needs to be understood and the objectives of the research clearly delineated. The critical variables must be identified, their distributions specified, if they are stochastic, and the interrelationships between them understood. For dynamic systems, care must be taken to insure that intermediate results are used as input to future processes. The system under study is then reduced to mathematical representations.

A model must be validated to see if it is properly mimicking the actual system under study. Three positions on validation of models have been taken. Rationalism reduces the problem of validation to specifying the basic undeniable assumptions underlying the behavior of the system. Empiricism insists that sense observation is the primary source and ultimate judge of knowledge. Facts, not assumptions must be used. Friedman, in his classic essay The Methodology of Positive Economics, argued the third view that validation of a model rests solely on its ability to predict behavior, regardless of the data and assumptions used.

Naylor summarized a multistage validation process which recognizes that each position is necessary but that neither of them is sufficient. The first stage requires the formulation of a set of postulates, or presuppositions, describing the behavior of the system. Stage two requires the analyst to attempt to validate the above postulates with statistical tests. Stage three consists of testing the model's ability to predict the behavior of the system being studied.

This research uses a simulation model called FLIPSIM V. FLIPSIM V and the modifications made to FLIPSIM V to accomplish this study have undergone stage one and two type validation. Stage 1 validation has been accomplished through a review, by researchers in economics and other disciplines, of the assumptions used. Stage 2 validation has been accomplished by a thorough review of intermediate results of the model to insure that the processes intended to be modelled are done so accurately. Since FLIPSIM contains no econometric equations there are virtually no parameters to be estimated and statistically tested. FLIPSIM V, unmodified, has been subjected to partial stage 3 validation as earlier predictions have been tentatively verified by empirical observation (Richardson and Nixon).

The above formulation and validation of a model can occur in a deterministic framework. Stochastic simulation models go a step further by imitating the random nature of key variables. Stochastic simulation requires a reliable source of random numbers distributed Uniform (0,1). These random numbers are used "to cover our ignorance of the details of the process used (Ripley, P. 16)."

Many sources of random numbers have been used in the past. Today most random numbers are generated in the simulation model by a random number generator. These generators produce a sequence of numbers which although completely deterministic have the same relevant properties as a sequence of random numbers. The numbers are completely deterministic because they are produced by an equation which will produce the same sequence of number every time if the first number is identical for each run.

Congruential generators are the most widely used generators. FLIPSIM V uses a congruential generator. Congruential generators are defined by

$$X_i = (AX_{i-1} + C) \bmod M \tag{32}$$

where the modulus M, multiplier A and shift C are real nonnegative integers. Uniform (0,1) random numbers are then produced by

$$U_i = \frac{X_i}{M} \, . \tag{33}$$

once the seed X_0 is specified.

Random numbers, being completely determined by a mathematical equation, will repeat themselves exactly if X_i ever equals X_0. The number of random numbers generated before X_i equals X_0 is called the period. The maximum period length is M. The period should be longer than the number of random numbers needed for a simulation run.

The choice of A, C and perhaps X_0 affects the period length. It is usual to choose M to make the modulus operation efficient, then to choose A and C to make the period as long as possible. Both empirical and theoretical tests can be used to validate that a sequence of random numbers is distributed independent uniform (0,1). Empirical tests are outlined well in Law and Kelton. Ripley has an excellent chapter on the theoretical tests.

Knuth lists two shuffling methods used to make random numbers "considerably more random." Intuitively shuffling should satisfy anyone's requirement for randomness in a computer-generated sequence. However, the shuffling method is little understood and has been theoretically analyzed only on simplified versions.

The random number generator used in FLIPSIM is the same used by DEC for its VAX compilers. The modulus is 2^{32}, the multiplier is 69069 and the shift is 1. Ripley describes this generator as "quite acceptable" (Ripley, p. 39), having small granularity and close spacing of latices. Shuffling is employed to further randomize the numbers generated.

An important aspect of random number generation is the ability to reproduce the exact same sequence of random numbers for different simulations starting with the same seed. This is a function of experimental design rather than random number generators. When two schemes are simulated they will yield outcome Y_1 and Y_2 with their respective variances. When comparing the mean difference of the two conditions a more precise estimate is obtained if the correlation between Y_1 and Y_2 is greater than zero. This follows from the fact that

$$V(Y_1-Y_2) = V(Y_1) + V(Y_2) - 2\,C(Y_1,Y_2). \tag{34}$$

Thus if the same sequence of random numbers is used to generate Y_1 and Y_2, the $C(Y_1,Y_2)$ is maximized and $V(Y_1-Y_2)$ is minimized (Ripley). Since the random numbers used in each simulation of each scheme are identical the comparison of schemes is facilitated. Intuitively, this means that no scheme is slighted by a bad draw of the cards to which another scheme is not subjected.

Uniform (0,1) random numbers are used in simulation to generate random numbers with other distributions which are representative of the variables used. The inverse-transform approach is a simple method when the inverse of a distribution function can be written in closed form such as the exponential, Wiebull and triangular distributions. The normal, gamma and beta distributions have no closed forms and thus cannot be produced using this method.

To generate Normal (0,1) random variables in pairs the "polar method is frequently used. It is described as follows:

1. generate U_1 and U_2 distributed IID U(0,1)
2. let $V_i = 2\,U_i - 1$, $i = 1,2$

   and $W = V_1^2 + V_2^2$
3. if W>1 go back to step 1, otherwise let $Y = \sqrt{\frac{(-2\ln W)}{W}}$, $X_1 = V_1 Y$ and

   $X_2 = V_2 Y$. X_1 and X_2 are IID N(0,1).

Triangularly distributed random variables are generated as follows:

1. generate U_1 distributed IID U(0,1)
2. $X = A + \sqrt{U_1\ (b - a)\ (m - a)}$ for $a < U_1 < m$

   $X = B - \sqrt{(1 - U_1)\ (b - a)\ (b - m)}$ for $m < U_1 < b$.

where X is IID Triangular(a, b, m)

Notice that to generate normal deviates two U(0,1) random numbers are necessary whereas to generate triangular deviates only one U(0,1) random number is necessary. In order to correlate the random numbers used in all simulations as previously discussed, those simulations which use triangular distributions have more than the necessary number of random numbers generated. Excess random numbers generated but not used are discarded at the appropriate time.

Previously, simulations were performed assuming either no correlation ($\rho = 0$) or perfect correlation ($\rho = 1$). This assumption does not realistically represent the system being studied and may significantly alter the results of the model. For example, if the correlation between two variables is assumed equal to zero, these variables are stochastically generated independent of each other. One variable's value may rise while the other falls in the same time period. But if their correlation is not equal to zero such an occurrence is highly unlikely. Assuming $\rho = 0$ in a simulation can introduce more variance into the system than actually exists. Conversely, assuming $\rho = 1$ may understate the variance that exists in a system.

Many recent simulation studies no longer make this assumption. Most of these studies utilize a procedure described by Clements, et al. which allows Monte Carlo simulation models to correlate two events. This procedure requires the assumption that the outcomes for each event are normally distributed. The equation used to correlate random events is :

$$Y = y + A W \tag{35}$$

where: Y = an n x 1 vector of generated values,

y = an n x 1 vector of expected values,

A = an n x n upper triangular matrix of coefficients which when multiplied by its transpose yields the covariance matrix associated with the n random events being considered,

W = an n x 1 vector of uniform (0,1) random numbers supplied by a random number generator.

The calculation of A as described by Clements et al. requires that the covariance matrix producing A be positive definite. Several computer programs (i.e.. MFACTOR by Richardson and Nixon) have been written to aid in the computation of A.

CHAPTER III

MODEL AND DATA

Introduction

The stochastic efficiency of various breeding schemes and management practices is analyzed using FLIPSIM V. FLIPSIM V is a firm level, recursive simulation model which simulates crop and livestock enterprises over a multi-period time horizon under various policy, production, financial and growth options. In its unmodified form it is able to model uncertainty in prices of both feed and livestock. It is modified to model swine enterprises with uncertain litter size and feed efficiency.

A ten year period from 1979 to 1988 is simulated. This period is characterized by two complete cycles in market hog prices and yearly fluctuations in feed ingredient prices. Hence, the swine operation is simulated over a variety of economic conditions. The production parameters of litter size and feed efficiency have the same mean and standard deviation throughout the ten year period.

Chapter three details 1) the model as modified to accomplish this research, 2) the representative pork production unit, 3) the data used and its justifications, and 4) the management strategies studied.

Simulation Model

The simulation model used in this research is a modified version of FLIPSIM V developed by Richardson and Nixon to allow analysis of the probable consequences of farm policies and income tax developments on typical farms. It is a firm level, recursive, simulation model which simulates annual production, farm policy, marketing, financial management, growth and income tax aspects of a farm over a multiple-year planning horizon. It simulates the outcomes of events and assumptions rather than attempting to optimize an objective function. Accounting equations and identities constitute the majority of the model.

FLIPSIM V is used because of its extensive logic relating to the marketing, financial and income tax aspects of production. These components are necessary for accurately modelling the pork production unit under study. The original livestock subroutine is modified to more realistically simulate pork production processes. The unmodified livestock subroutine is developed for beef and is completely deterministic in its modelling of the production processes. The herd size and the amount of feed required to raise the animals are set at some specified number by the analyst. FLIPSIM V, as used in this study, is modified to strengthen the livestock production subroutine. The following paragraphs discuss the methods and rationale for making both litter size and feed efficiency stochastic when modelling pork production.

The ability to simulate stochastic litter size gives a more realistic view of reproduction uncertainties on the number of animals born and raised. The number of pigs weaned per farrowing sow per year is stochastic each year of the simulation. The mean and standard error for each year are constant. The number of animals weaned, less a 1.5% death loss, are raised in the facilities provided.The model allows for the number of animals raised to market weight to be held at some constant or allowed to vary from year to year as the number of pigs weaned varies. If the number of animals raised is held constant, the model's logic will buy or sell feeder pigs to maintain the desired herd size. This study of breeding schemes and managerial strategies is performed assuming a variable market herd size. This feature gives a dynamic component to the model by allowing the average fixed cost of production to vary depending on the efficiency of each period's production.

The model assumes a constant daily feed consumption for the breeding stock but stochastically simulates the feeding regime of market animals raised. The average pounds of feed required to add one pound of live animal is stochastically determined each period from a given mean and corresponding standard error. This feed efficiency parameter is then multiplied times the number of pounds gained per animal from weaning to market and by the number of animals being fed. The whole herd feed efficiency will vary with time as the market herd size changes and as feed efficiency changes. This adds another dynamic component to the model. Both average variable and average fixed cost will change with the stochastic parameter of feed efficiency. The whole herd feed efficiency when both parameters are variable and dynamically interact is greater than if either of the parameters were considered in isolation.

A schematic of the simulation model, as used in this thesis, is given in Figure 9. The model simulates the swine production enterprise for a ten year period, repeating this simulation for 100 iterations. A brief summary of each subroutine without referring to actual input values used is presented below.

Stochastic Parameters. Each year the parameter values specified as stochastic are randomly generated. A random number generator draws a number uniformly distributed between 0 and 1 which is used in the appropriate

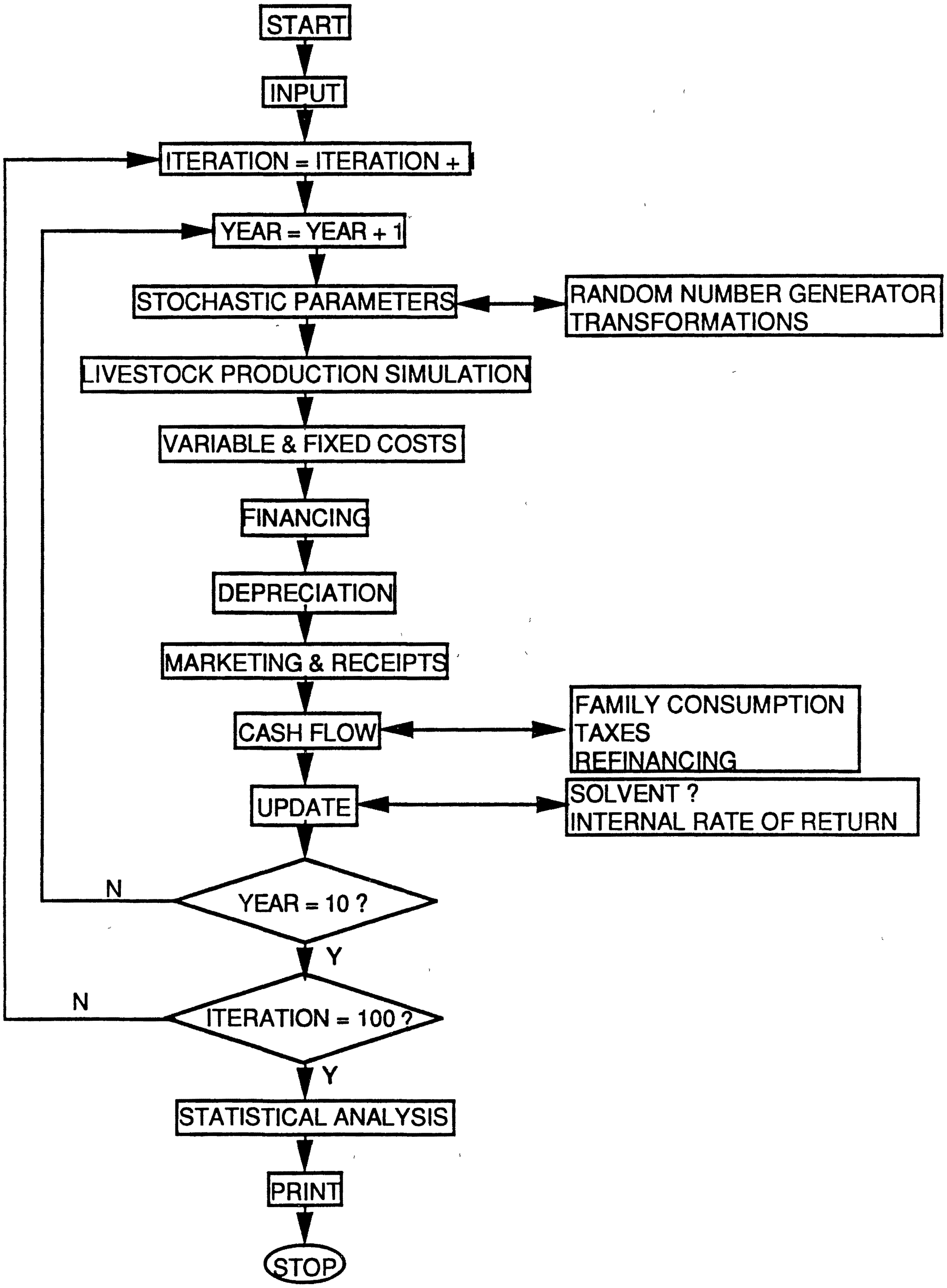


Figure 9. Schematic of FLIPSIM V

algorithm to generate univariate normal or triangular distribution values for reproductive efficiency and feed efficiency and multivariate normal distribution values for prices.

Livestock Production Simulation. The livestock subroutine first updates the breeding herd to insure that a sufficient number of females and boars are in the operation. Cull sows are sold and the number of gilts necessary to maintain the constant size breeding herd are separated from the market hogs. Boars are also bought and sold yearly. Any cost recovery computations on boars are also performed here for use in computing the producer's tax liability.

The stochastically generated number of pigs weaned per year is then multiplied by the number of females in the breeding herd to compute the number of feeder pigs raised. Replacement gilts are obtained from these feeder pigs.

The feed computations assume constant average yearly consumption by the breeding herd and piglets prior to weaning. The feed consumption per pig is computed using the stochastically generated feed efficiency parameter during the growing/finishing phase of production. The total amount of feed necessary to raise each pig is divided between grower and finisher ration using a simple percentage. The total amount of feed necessary for the feeding of all market hogs is the product of this feed requirement per pig and the number of pigs raised. Each livestock group (sows, boars, replacement gilts, starters, growers, and finishers) is fed a separate ration. Each ration is composed of grain sorghum as an energy source and hog concentrate as a protein and vitamin/mineral source. The necessary hundredweight of each feed ingredient is computed and totalled.

The receipts from livestock sold are then calculated based on the number in each group sold, their sale weight, and a stochastically generated price.

Feed ingredient costs are also computed from the total hundredweight fed and their stochastically generated price.

Variable and Fixed Cost Subroutine. The nonfeed variable cost of production is calculated for each type of animal and summed to obtain total input costs. Utilities and labor are calculated on a per sow basis while shipping and medicine are calculated on a per hog marketed basis. Interest cost for operating capital is calculated based on the farm's total variable cost of production, the annual interest rate for operating capital and the fraction of the year an operating loan is used. Certain costs such as accountant and legal fees and insurance are considered fixed with regard to the number of pigs. Annual values for exogenous fixed costs are calculated by inflating their initial value by the appropriate annual percentage changes.

Financing Subroutine. Loans obtained to purchase buildings and equipment are repaid per a fixed payment schedule. The interest rate, length of loan, and size of loan determine the payment schedule. The breeding stock are assumed not to require a loan since all females are raised and boar purchase price is not a major expense.

Depreciation Subroutine. The facilities are depreciated according to the tax code in effect for that specific year of the simulation. This depreciation cost is used when computing the producer's tax liability. The equipment is sold and replaced after it reaches its specified economic life (not necessarily equal to its depreciation life). Livestock are not depreciated because boars are purchased, held for one year and sold; females are raised on the farm. Property taxes are the appropriate property tax rate multiplied by the market value of land and buildings owned in the previous year.

Marketing and Receipts Subroutine. All of the cash costs generated in the previous subroutines are charged against the producer in this subroutine.

Cash Flow. An annual cash flow is simulated from the receipts and expenses generated (including family consumption) above. Family consumption is variable each year per equation 36 with minimum and maximum consumption specified as \$11,340 and \$31,500 (1979 dollars), respectively.

$$\text{Family consumption} = 3.232 + .377\ \text{CUS} + .682\ \text{INCOME} \tag{36}$$

where CUS = Consumer unit size (number of individuals in family) and
INCOME = After-tax income.

Taxes are paid and any refinancing of debt, if necessary, is performed.

Update Subroutine. If the farm's financial measures reach a predetermined minimum value of 25% long term or intermediate term equity, the farm is declared insolvent. The assets are sold and the money received invested until the end of the ten-year planning horizon. If the farm is solvent, an internal rate of return is calculated for that year.

Statistical Analysis Subroutine. The results of key economic and production variables are recorded at the end of each iteration for future statistical analysis. Key variables reported in this study include the after tax net present value, the average annual income, the internal rate of return at the end of the last year, number of pigs weaned per sow per year and feed conversion. The mean, standard deviation, coefficient of variation, minimum and maximum of each key variable is reported from this analysis. If the simulation is not for year 10, the ending situation of the simulation becomes the beginning of the next year's simulation. If the simulation is for year 10, the model reinitializes the farm to the beginning situation used for iteration one before proceeding with each new iteration. Additionally, the farm operator's after tax net present value (NPV) from each iteration is saved and listed in ascending order to give a cumulative probability distribution. The NPV is defined as the discounted yearly change in the operator's net worth.

The modified FLIPSIM V model is used to simulate 27 different breeding schemes. The NPV of each iteration is recorded on a separate memory file for use in stochastic dominance analysis. A stochastic dominance algorithm by Cochran and Raskin is used for all stochastic analyses. The algorithm performs quasi- first and second degree stochastic dominance, generalized stochastic dominance and computes the amount by which a dominant option can be lowered before it is no longer considered dominant, given specific risk aversion coefficients.

140 Sow Farrow-to-Finish Confinement Operation

A 140 sow farrow-to-finish confinement operation is modeled for a hypothetical Oklahoma producer for the period 1979 to 1988. The unit is assumed built in 1976. The three year period between building and simulated production allows for all start-up irregularities to pass.

Production Facilities Requirements

One hundred acres of land are used for the representative farm. Ten acres of land are required for production facilities, feed mill, lagoon and surrounding buffer. An additional 90 acres of land are available for housing and waste disposal. Land values are northeastern Oklahoma land values listed in Oklahoma Agricultural Statistics. A schematic of the production facilities used in this thesis is presented in Figure 10.

The facilities costs are obtained by discounting 1987 estimated costs to 1976 using indices of prices paid by farmers for buildings and equipment as published in the USDA Annual Price Summaries. The investment figures

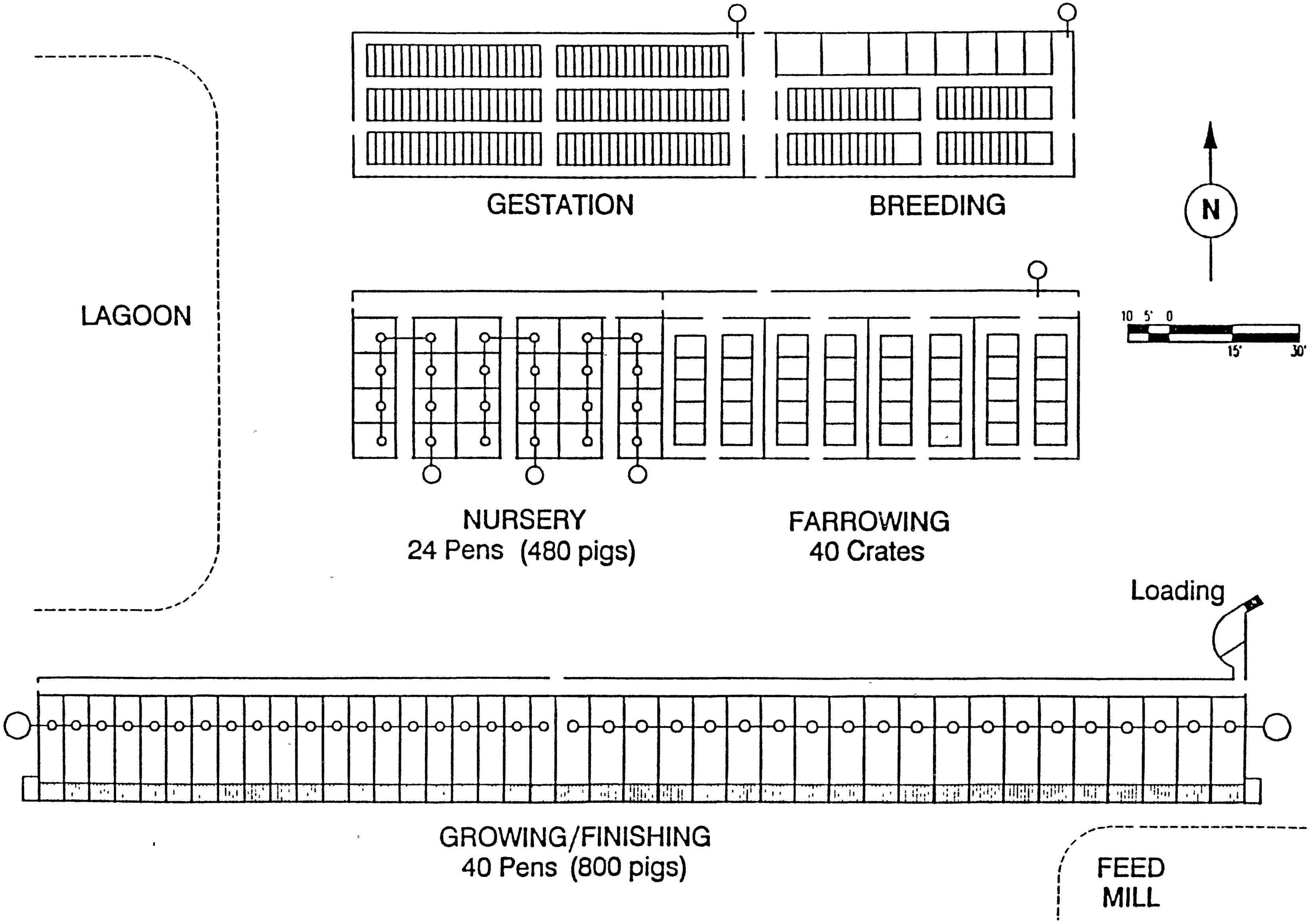


Figure 10. Schematic for a 140 Sow Farrow-to-Finish Confinement System

represent a production system where all facilities except the breeding and gestation facilities are in complete confinement. Included in the system are feed storage facilities and an automated feed mill. Table 2 lists the various components of the complete complement of facilities, an estimate of respective investment requirements in 1987 and the discounted 1976 costs as used in the model. The thirteen year span from construction to the end of the simulation is short enough so that most of the facilities do not need to be replaced. This prevents the rejuvenation of facilities from becoming a major consideration in the analysis.

Operations Summary

The sow herd is divided into seven groups of 20 farrowing sows. Each sow group occupies two farrowing rooms. Sows are moved into the farrowing rooms 110 days after introduction to the boars for breeding and are expected to farrow within ten days after arrival. Weaning occurs when the pigs are from 28 to 35 days old. Sows are then returned to pens near the boars to await breeding. Weaned pigs are moved to the nursery.

All weaned pigs from one group of 20 sows are moved into a nursery at the same time. Pigs stay in the nursery for about 56 days and reach an approximate weight of 75 pounds. Pigs are then moved to the growing/finishing facilities for about 95 days, reaching a market weight of about 230 pounds.

There is a seven to ten day clean up period available for each of the facilities after one group of pigs is removed and before another group enters. An example of a production schedule is given in Figure 11. Sixteen and one half hours of labor per sow per year are assumed required. Family members are expected to provide all labor and do not receive an explicit wage for it.

TABLE 2

FACILITIES, MACHINERY AND EQUIPMENT FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT OPERATION

Facilities	Total Cost	
	1987 dollars	1976 dollars
Farrowing Facilities		
Equipment	19,200	9,548
Building	44,800	30,739
Nursery Facilities		
Equipment	9,360	4,655
Building	21,840	14,985
Finishing Facilities		
Equipment	17,600	8,752
Building	70,400	48,304
Gestation/Breeding Facilities		
Equipment	2,700	1,343
Building	15,300	10,498
Subtotal		
Equipment	48,860	24,298
Building	152,340	104,526
Support Facilities		
Lagoon	7,500	5,146
LP Supply	1,000	686
Water Delivery System	3,000	2,058
Loading Chute	500	343
Pickup	12,000	5,250
Stock Trailer	4,000	1,989
Generator	4,000	1,989
Sprayer-Cleaner	800	398
Feed Mill and Storage	30,000	14,919
Subtotal	62,800	32,778
Total	264,000	161,602

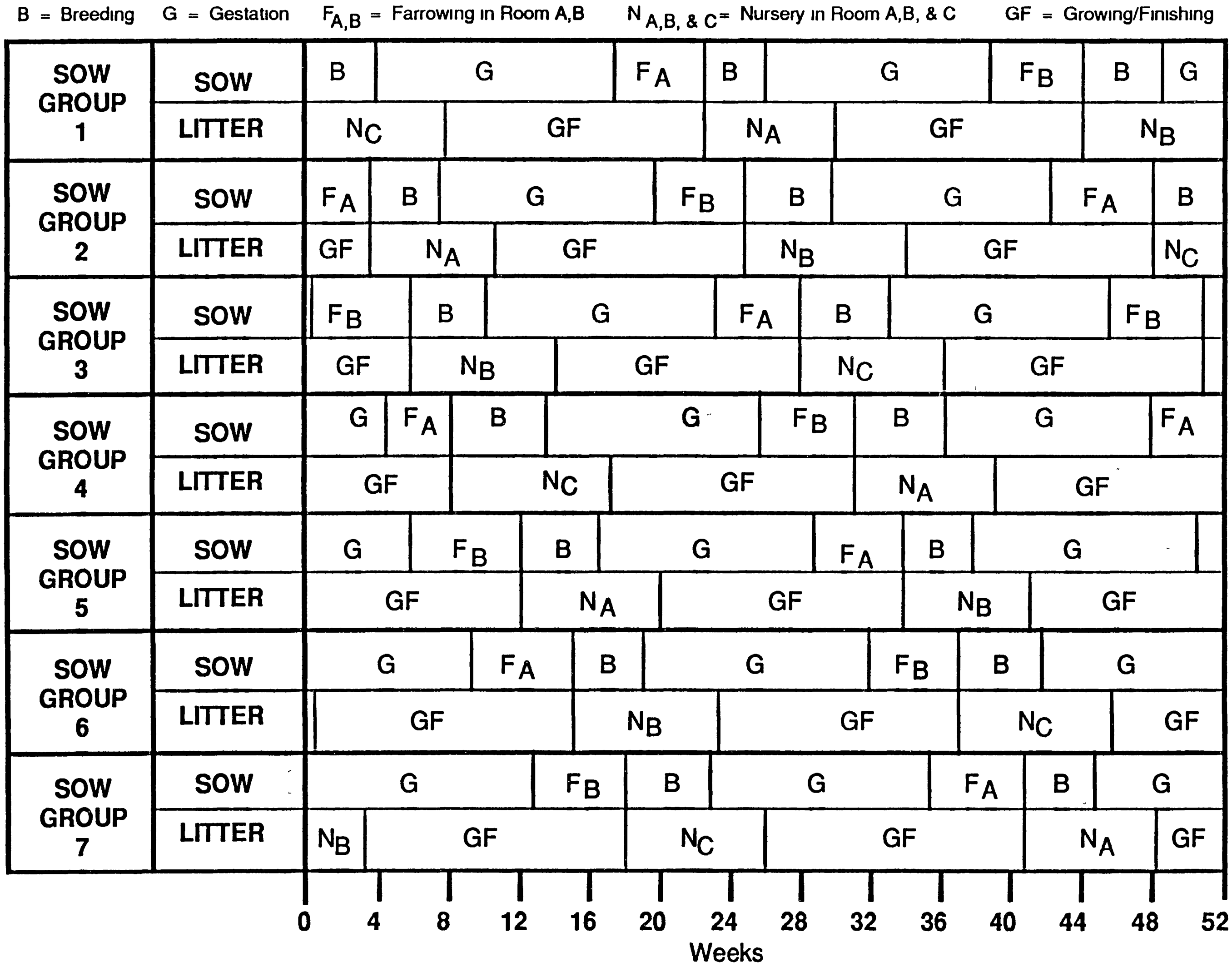


Figure 11. Production Schedule for a 140 Sow Farrow-to-Finish Confinement System

Production Assumptions

The basic production assumptions used in this study are presented in Table 3. One hundred sixty one sows and gilts are required to obtain 140 bred females with a mean conception rate of 87%. Sows comprise 68.4% of the farrowing females while gilts comprise 31.6%. Market hogs are raised from the pigs farrowed by the sows. It is assumed that 1.5% of the weaned pigs will die before attaining market weight of 230 pounds. Each time a group of 23 sows and gilts is bred, seven females are culled from the herd. Each group of females is expected to farrow 2.42 times per year. All feed is assumed to be mixed on the farm. Per animal ration requirements and the percentages of sorghum grain and concentrate necessary for each ration are given in Table 4.

Financial Assumptions

The required facilities are assumed purchased in 1976 using some borrowed capital. At the start of the simulation, the debt to asset ratio is assumed 50%. Specifying the loan lives and interest rates, FLIPSIM calculates the original loan values and current outstanding debt. The financial assumptions for the farm are listed in Table 5.

Typically longer term loans have a higher interest rate to account for the maturity risk premium. However, during periods of inflation, inverted yield curves characterized by lower long term interest rates are seen. Such is the case for 1976 when the loans necessary for production are obtained. The interest rate data, collected from the US Agricultural Statistics, is used as reported. The long term interest rate is the average rate charged by the Federal Land Bank in 1976; the intermediate term rate is the Production Credit Association rate in 1976.

TABLE 3

PRODUCTION ASSUMPTIONS FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT OPERATION

Animal Class	Percentage	Number	Sale Weight (pounds)
Breeding Herd			
Total Number of Females	100.0	161.0	
Conception Rate	87.0		
Total Farrowing Females		140.0	
Sows	68.4	95.5	400
Gilts	31.6	44.5	325
Farrowings per Female per Year		2.42	
Total Number of Boars		11 to 12[a]	425
Average Death Loss of Weaned Pigs	1.5	28.6 to 44.0[a]	
Average Number of Market Hogs per Year		1876 to 2889[a]	

[a] actual number depends on the breeding scheme

TABLE 4

ANNUAL RATION REQUIREMENTS FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT OPERATION

Animal Class	Total	Protein	Ration Composition	
			Sorghum	Concentrate
	(cwt.)	(%)	(%)	(%)
Sows	23.11	14	82	18
Replacement Gilts	9.98	14	82	18
Boars	18.25	14	82	18
Starters	1.5	18	73	27
Growers	a	16	77	23
Finishers	a	14	82	18

[a] depends on the feed efficiency and number of pigs weaned of each breeding scheme.

TABLE 5

FINANCIAL ASSUMPTIONS FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT OPERATION

Measure	Value
Initial Financial Ratios	
Whole Farm Debt to Asset	.5
Equity to Asset	.5
Leverage	.99
Long Term Loan Assumptions	
Loan Life (years)	15
Interest Rate (%)	8.66
Amount of Loan in 1979 ($)	99,100
Intermediate Term Loan Assumptions	
Loan Life (years)	10
Interest Rate (%)	8.24
Amount of Loan in 1979 ($)	27,075
Minimum Equity Ratio Necessary for Solvency	.25

Data Description and Explanation

Introduction of Pork Production Data

Heterosis, or hybrid vigor, is the genetic concept where the offspring of two parents of differing genetic makeup perform better than the average of the parents. Crossbreeding experiments on swine have been a major research emphasis at Oklahoma State, Iowa State, North Carolina State, Purdue and Auburn Universities. Much data exists in the animal science literature detailing the results of these experiments. Regrettably, much of this data is reported in a form difficult to use in stochastic economic analysis.

The shortcomings of the data for economic analysis lie in three areas. First, the data were collected specifically to estimate a value of heterosis. This estimate is not immediately useful in economic analysis. Second, there are gaps in the reported data which are useful for economic analysis. Different studies emphasized different characteristics and hence some necessary characteristics for this study are not reported. Third, the standard errors necessary for stochastic model are not always reported.

Production Data

Despite some limitations, there exists much valuable and useful data for stochastic economic analysis. Particularly Oklahoma State University has maintained a breed evaluation program for several years and reported the results with sufficient statistics. This research utilizes data from the Southwest Livestock and Forage Research Station , El Reno, Oklahoma. The data cited were collected in four separate trials completed between the years 1971 and 1977 and reported in the Journal of Animal Science (Johnson, Omtvedt and Walters (1973 and 1978), Johnson and Omtvedt (1973b), and Wilson and

Johnson). All four experiments were conducted on various crosses of Yorkshire (Y), Duroc (D) and Hampshire (H) breeds of swine. All four measured reproductive performance of the crossbreeds and/or the feedlot performance of their respective progeny. Using only OSU data assures that management and environmental impacts on results are at a minimum.

It is assumed that for pork producers the two most critical production variables, which can also serve as proxies for the particular breeding schemes, are feed efficiency and litter size. Feed efficiency is defined as pounds of live animal gain per pound of feed. Litter size is taken as number of live pigs at 42 days. The number of pigs born alive and the survivability of these pigs or the weight of a litter at 0, 21 or 42 days could also have been used but it was thought that the number alive at 42 days best fits the production assumptions discussed earlier. Along the same lines, other feedlot characteristics such as days to 100 kg or average daily gain could have been used. Again because the pounds of feed per pound of gain determines the amount of feed consumed in a pork production facility and feed is one of the major costs of production, this measure is deemed most critical. Edwards, van der Sluis and Stevermyer report the importance of these two characteristics in their study of the determinants of profitability of farrow-to-finish pork production.

These two traits were both reported to be significantly different for different breeds and breeding schemes by using one way classification to evaluate the data garnered from the studies. The two traits are also assumed to be independent by animals geneticists. A review of the literature failed to find estimates of correlation between these traits. Distributions are assumed normally distributed under good management.

The reporting of the data was not totally consistent across time but it was sufficient to give adequate data for an economic simulation. All the reports contained the mean litter size at 0, 21 and 42 days and the mean feed efficiency of the breed crosses. Data reported by Johnson and Omtvedt (1973) contained litter size standard errors. The data reported by Johnson et al. (1973) did not contain estimates of the standard error for pounds of feed per pound of gain; those reported by Johnson, et.al. (1978) reported both standard errors; those by Wilson and Johnson (1981) reported only the range of standard errors for both traits.

Where two or more articles report data for the same breeding scheme, both sets of data are used. A weighted average of the litter size and feeding efficiency are computed in such cases. The feed efficiency reported is much higher than typically observed in practice so a 10% "waste factor" is computed by the model. SMFBMA records show farrow-to-finish operations to have a whole herd feed efficiency between 3.91 and 4.09 pounds of feed per pound of gain for the last 5 years. The waste factor brings the simulated farms whole herd feed efficiency more in line with these figures (approximately 3.9 to 4.0 depending on the breeding scheme). The difference may be attributable to such things as feed spillage and rodent damage that exists on hog production units but may not be taken into account at research stations. The input reported in Table 6 do not reflect this spillage factor but report the animal science research results.

This research is conducted assuming equal variances in litter size across breeds for the following reasons. 1) One test of equal variances is the F-test which consists of dividing the maximum variance by the minimum variance. When an F-test is performed on only one data source at a time, the null hypothesis of equal variances cannot be rejected at the .20 significance level. When an F-test is run on all data being used, the null hypothesis of equal variances can be rejected at the .10 significance level; however, Johnson,

TABLE 6

DESCRIPTIVE CHARACTERISTICS OF 27 HOG BREEDING SCHEMES ANALYSED

Breeding Scheme	Number Weaned	Pooled Standard Error	Pounds gain / Pound feed	Pooled Standard Error	Boars Needed
			Purebreds		
DxD	15.06	1.081	.3000	.0048	11
HxH	14.51	1.081	.3070	.0048	11
YxY	19.74	1.081	.3240	.0048	11
			Two-Breed Terminal Crosses		
DxH	17.45	1.081	.3174	.0048	11
DxY	20.32	1.081	.3217	.0048	11
HxD	16.39	1.081	.3160	.0048	11
HxY	19.56	1.081	.3310	.0048	11
YxD	19.57	1.081	.3171	.0048	11
YxH	17.56	1.081	.3278	.0048	11
			Three-Breed Terminal Crosses		
DxYH	21.36	1.081	.3286	.0048	12
HxYD	20.93	1.081	.3310	.0048	12
YxHD	20.09	1.081	.3137	.0048	12
DxHY	21.77	1.081	.3292	.0048	12
HxDY	21.09	1.081	.3319	.0048	12
YxDH	20.30	1.081	.3140	.0048	12
			Two-Breed Terminal Backcrosses		
DxDH	20.41	1.081	.3194	.0048	11
DxHD	20.21	1.081	.3192	.0048	11
DxDY	19.50	1.081	.3251	.0048	11
DxYD	19.34	1.081	.3242	.0048	11
HxDH	18.30	1.081	.3122	.0048	11
HxHD	18.10	1.081	.3120	.0048	11
HxHY	19.00	1.081	.3222	.0048	11
HxYH	18.60	1.081	.3215	.0048	11
YxDY	20.63	1.081	.3155	.0048	11
YxYD	20.47	1.081	.3146	.0048	11
YxHY	20.16	1.081	.3198	.0048	11
YxYH	19.76	1.081	.3191	.0048	11

Note: D = Duroc, Y = Yorkshire, H = Hampshire et.al.(1978), consistently report higher variance than Johnson and Omtvedt. 2) Ordering the breeding schemes by variance using one data source does not yield the same ordering using another source of data. Neither an ordering of breeding schemes (i.e. HxD and DxH) nor an ordering of breeding systems (i.e. purebred, two- and three-breed terminal crosses) could be discovered. Hence, one breeding scheme cannot be shown to consistently have higher (lower) variance than another.

The variances across breeding schemes for feed efficiency were also subjected to an F-test and found not statistically significant at the .20 level regardless of the procedure used. The variances reported for litter size and feeding efficiency were used to determine a pooled variance. The pooled variance is used for all breeding schemes.

Johnson, et.al (1973) used only gilts in their research while the other two efforts measured reproductive efficiency of both gilts and sows. One of these converted their data to gilt equivalents while the other did not. The one which did not use all gilts or report their data in gilt equivalents detailed the composition of the animals and included an analysis of the reproductive efficiency difference between gilts and sows. This additional data was sufficient to convert the reported means for litter size to gilt equivalents so that data from the three trials were comparable.

The comparison between gilts and sows also yields valuable data necessary for determining the litter size statistic for the simulated farm. The modelled farm contains gilts and sows in different proportions than any research experiment. Thus the actual values used as litter size is a combination of gilt litter size and sow litter size. The equal variances are again upheld for sow and gilt data.

Breeding stock is assumed replaced either due to failure to conceive or after the fourth farrowing. The modelled farm followed a typical pork production practice of replacing breeding stock with gilts raised on the farm. This requires that the breeding herd be composed of mini herds which produce replacement gilts. For example, The HxDY breeding scheme used a Hampshire boar mated to a Duroc-Yorkshire cross for the majority of its matings (referred to as the terminal group). To supply the Duroc-Yorkshire gilts a mini herd of purebred Yorkshires females was maintained, and Yorkshire and Duroc boars were mated to these females (non-terminal groups).

There are two ways to set up the replacement stock herds in the two-breed terminal backcrosses and three-breed terminal crosses. Both are used in this analysis and reported in Table 6. The first letter in the notation represents the sire breed. The letter combination after the "x" represents the breed of dam. The last letter of the breed of dam notation represents the smallest purebred herd necessary to maintain the breeding scheme. The letter combination (order important) represents the intermediate size breeding herd necessary to maintain the breeding scheme. Within this herd, the first letter represents the breed of sire and the second letter represents the breed of dam. Table 7 gives examples of how the above schemes work.

Two-thirds of the females born in the non-terminal groups were used for replacement stock. This allows for on farm selection of breeding stock for improvement. The proportion of breeding stock in each group necessary to provide sufficient replacement animals is detailed in Table 7.

Alternatively, crossbred replacement gilts could be purchased from an outside source. This requires a reliable source of replacement gilts and the ability to make quality selections from that source. Purchasing replacement gilts also increases the chance of introducing disease to the herd. For an operation

TABLE 7

HERD COMPOSITION OF VARIOUS BREEDING SYSTEMS

Type of Operation	Proportion of Breeding Herd (%)	Number of Boars	Offspring Disposition
Purebreds			
Purebred (eg. YxY)	100	11	Slaughter
Two-Breed Terminal Backcrosses			
Purebred (eg. YxY)	4	1	Replacement Gilts
Two-Breed Crosses (eg. DxY)	16	2	Replacement Gilts
Two-Breed Backcross (eg. DxDY)	80	9	Slaughter
Total		12	
Three-Breed Terminal Crosses			
Purebred (eg. YxY)	4	1	Replacement Gilts
Two-Breed Crosses (eg. DxY)	16	2	Replacement Gilts
Three-Breed Cross (eg. HxDY)	80	9	Slaughter
Total		12	
Two-Breed Terminal Crosses			
Purebreed (eg. YxY)	19	2	Replacement Gilts
Two-Breed Crosses (eg. DxY)	81	9	Slaughter
Total		11	

as large as the one modelled it is not unrealistic to assume that replacements are raised on the farm.

All of the breeding schemes modelled are terminal crosses. Historically, rotational crosses fit production systems and terminal crosses are not used by commercial producers (Ahlschwede, et.al.). No data exists on the litter size and feeding efficiency of rotational crosses. Animal science simulation models incorporating heterosis could provide these data, though without variances (this may not be a large hindrance since there is ample evidence to justify equal variances and assigning a pooled variance to such data). Geneticists show that terminal crosses are superior users of heterosis so production would be expected to be superior with terminal crosses. Managers are adopting terminal crosses as production facilities become larger and competition forces producers to increase efficiency.

The number of boars needed to maintain the breeding schemes are also given in Table 7. The two breed terminal backcross requires 12 boars; 1 to maintain the purebred herd and 11 to maintain the cross and backcross aspects of the herd. The three breed terminal cross also requires 12 boars; 1 for the purebred group, 2 for the two breed cross and 9 for the three breed cross. The one boar used for the purebred part of the above two schemes is under-utilized. A producer might use artificial insemination rather than keep a boar on the farm for this group. This research assumes natural breeding. The two breed terminal cross requires only 11 boars; 2 for the purebred and 9 for the cross. The boars are more optimally used in this scheme for this size firm.

Price Data

The prices used in this thesis represent Oklahoma prices for livestock and feed ingredients. Monthly Oklahoma City data are available from 1959 for market hogs, sows and grain sorghum (USDA Livestock Detailed Quotations). Oklahoma hog concentrate prices are reported on a quarterly basis during the period 1986 through 1988, on a monthly basis from 1977 to 1985, and three times a year from 1959 to 1976 in the USDA Agricultural Prices (See Figures 12 and 13). All mean annual prices used in the simulation model (1979-1988) represent simple averages of either the monthly or quarterly prices reported (see Table 8). Since pork production is considered continuous with the operation having livestock born and marketed each month, simple averages are most realistic. Using annual weighted averages reported by the USDA would give too much emphasis to months in which the majority of a product is sold in the US but not necessarily on a continuous production farm.

Market hog prices represent US #1-2, 220-230 pound barrows and gilts. Sow prices are for US #1-2, 400-500 pound sows. Data on boar and non-breeder gilt prices are unavailable. Boar and gilt prices were assumed 65% and 90%, respectively, of market hog prices (Plain). The perfect correlation between market hog prices and boars and non-breeder gilts is not too bold an assumption given that sow prices have been nearly perfectly correlated with market hog prices since 1959. The boar and non-breeder gilt marketings account for approximately 2% of the total pounds marketed so any simplifying assumption on their price should have negligible effect on the producer's income.

Sorghum price data used are prices received by farmers in Oklahoma. To these, a 10% markup has been added to reflect the margin of distributors and any other marketing costs (Richardson and Nixon). The hog concentrate price data used are reported as prices paid by farmers.

The distribution associated with the prices is assumed normal and multivariate across all livestock and feed categories. Hence, one covariance

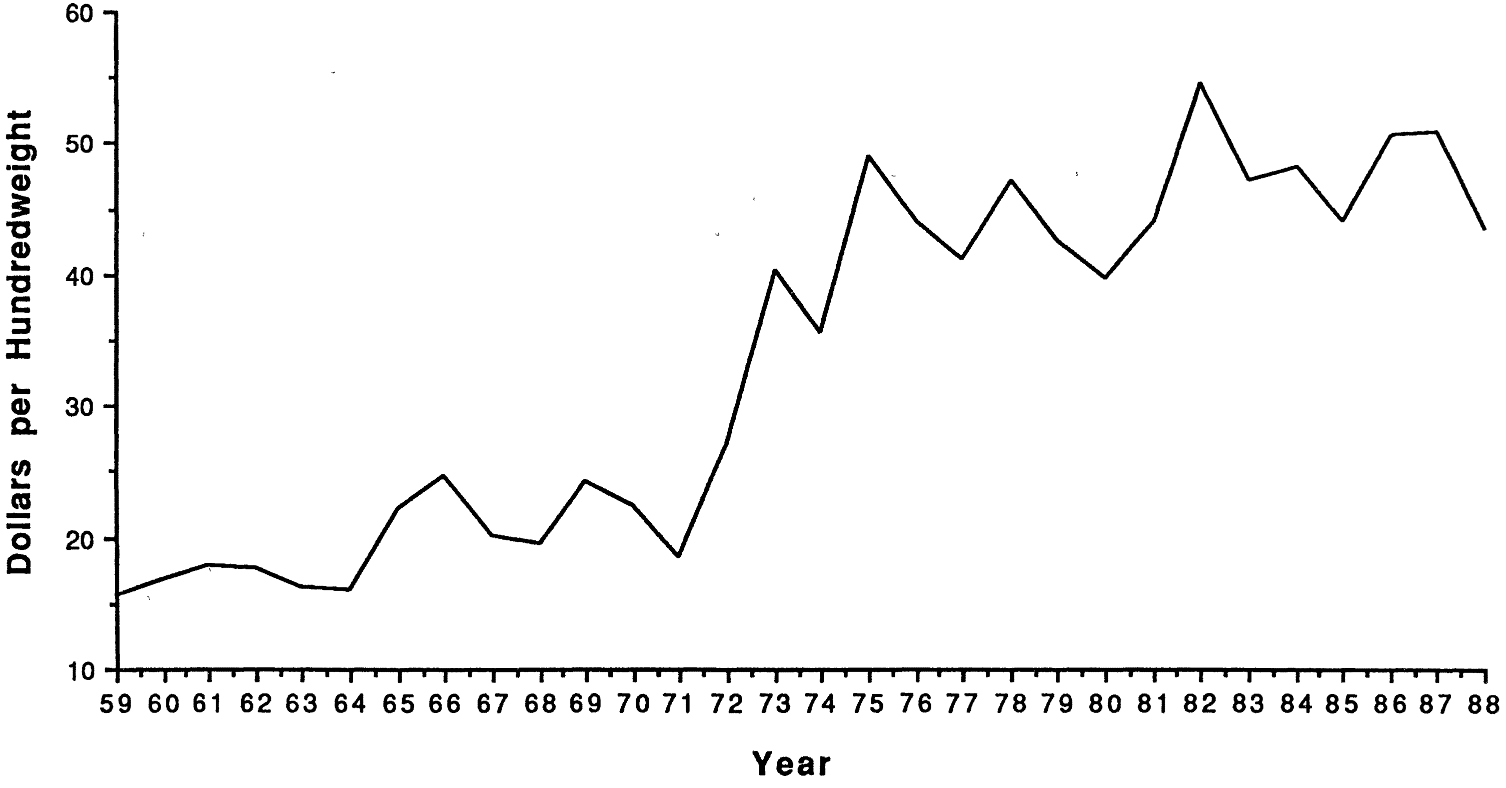


Figure 12. Oklahoma Average Annual Market Hog Prices (1959 to 1988)

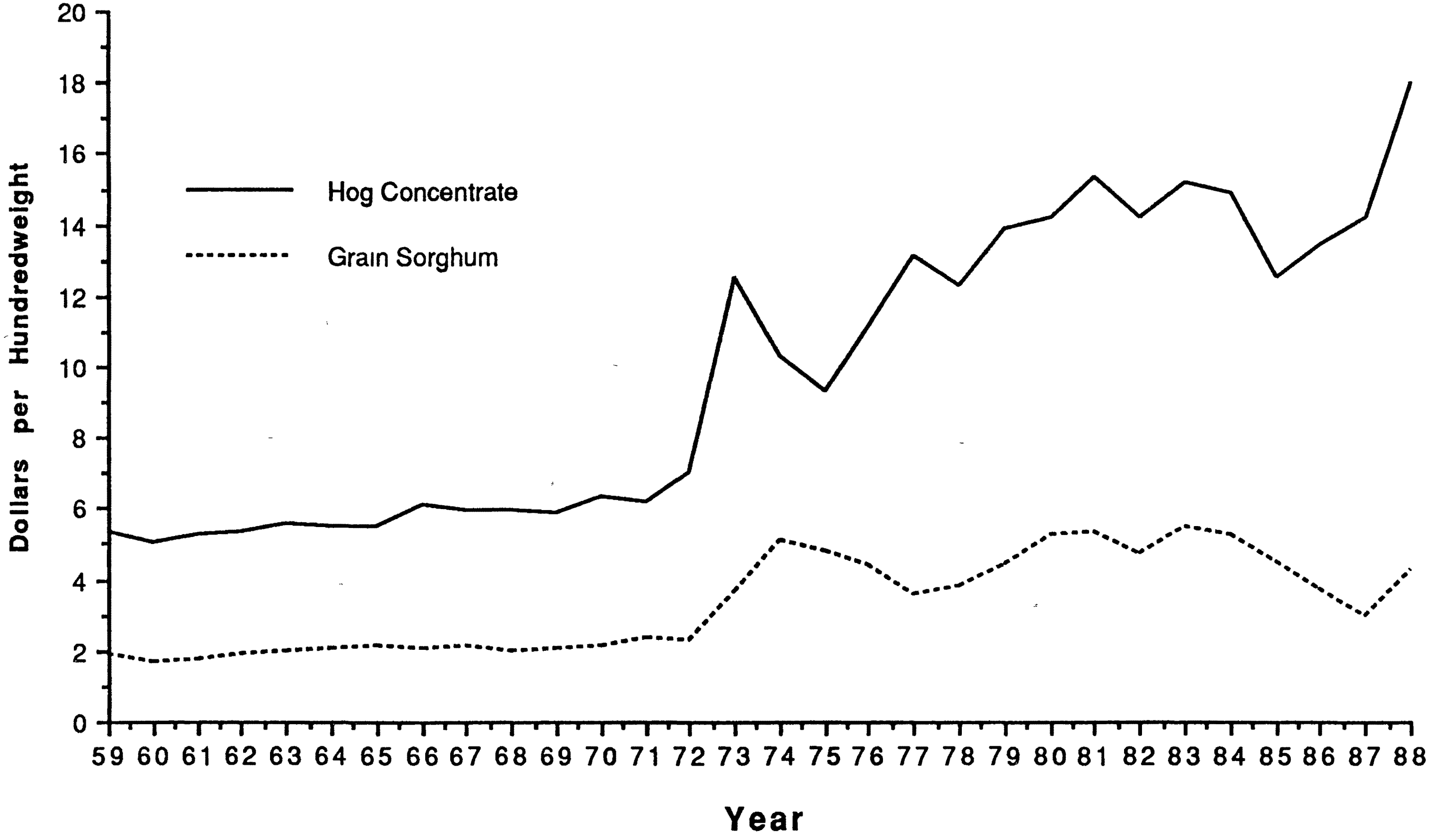


Figure 13. Oklahoma Average Annual Sorghum and Hog Concentrate Prices (1959 to 1988)

TABLE 8

AVERAGE ANNUAL OKLAHOMA LIVESTOCK AND FEED PRICES

Year	Market Hogs	Sows	Gilts	Boars	Hog Concentrate	Sorghum
			(dollars/cwt.)			
1979	42.69	34.83	38.42	27.75	13.86	4.44
1980	39.77	33.89	35.79	25.85	14.23	5.23
1981	42.99	35.35	39.59	28.59	15.33	5.32
1982	54.55	48.24	49.10	35.46	14.17	4.75
1983	47.10	40.28	42.39	30.62	15.21	5.52
1984	48.18	42.52	43.36	31.32	14.92	5.29
1985	44.19	38.36	39.77	28.72	12.50	4.50
1986	50.62	44.20	45.56	32.90	13.42	3.74
1987	50.99	42.36	45.89	33.14	14.19	3.01
1988	43.54	31.83	39.19	28.30	18.01	4.31
mean	46.56	39.19	41.91	30.27	14.58	4.20

matrix for all prices is computed using SAS. This matrix is used to generate the upper triangular A matrix used in FLIPSIM to generate random, multivariate normal deviates on prices.

From Figures 12 and 13 it is observed that all prices involved were affected by inflation and political decisions in the 1970's. To derive a covariance matrix which did not unduly take this period into account, the prices are detrended. The index of prices received by farmers in the US (1910-1914 = 100) as reported by USDA Agricultural Prices is chosen to detrend the data. It is recognized that sorghum and hog concentrate are prices paid by farmers in this study. However, the price paid has a strong, direct correlation to the prices received for these commodities since they too are agricultural products. This index is deemed best for accounting for the peculiarities present in the variance.

The resulting covariance matrix and corresponding correlation matrix are shown in Tables 9 and 10, respectively. The fact that boar and non-breeder gilt prices are assumed a constant percentage of market hog prices, accounts for the correlation of .9999 between these prices. The correlation of .9788 between market hog price and sow price is extremely high and is associated with a high statistical probability of rejecting the null hypothesis that their correlation equals zero. The correlation between market hog price and sorghum and hog concentrate price are approximately .1 each. The null hypothesis of these correlations being equal to zero cannot be rejected at the .10 significance level. However, the covariances between these factors are used in the model on the theoretical grounds that sorghum and concentrate prices are affected by hog numbers which also affects hog prices. The correlation between sorghum and hog concentrate is -.2 and the null hypothesis that the correlation equals zero is rejected only at the .25 significance level. Again, this correlation, though statistically weak, is allowed to interact in the model.

TABLE 9

COVARIANCE MATRIX OF DETRENDED OKLAHOMA LIVESTOCK AND FEED PRICES (1959 - 1988)

	Sorghum	Hog Concentrate	Sows	Gilts	Boars	Market Hogs
Sorghum	.011469	-.004795	.012845	.009792	.007020	.010828
Hog Concentrate	-.004795	.043963	.009180	.020922	.015215	.023342
Sows	.012845	.009180	1.08978	1.00129	.722574	1.11268
Gilts	.009792	.0209217	1.00129	.960016	.692868	1.06691
Boars	.007020	.015215	.722574	.692686	.499809	.769816
Market	.010828	.023342	1.11268	1.06691	.769816	1.18572

TABLE 10

CORRELATION MATRIX OF DETRENDED OKLAHOMA LIVESTOCK AND FEED PRICES (1959 - 1988)

	Sorghum	Hog Concentrate	Sows	Gilts	Boars	Market Hogs
Sorghum	1.0000	-.21353	.11489	.09332	.09272	.09285
	0.0000	.2572	.5455	.6238	.6260	.6255
Hog Concentrate	-.21353	1.0000	.04194	.10184	.10264	.10224
	.2572	0.0000	.8258	.5923	.5894	.5909
Sows	.11489	.04194	1.0000	.97893	.97906	.97883
	.5455	.8258	0.0000	.0001	.0001	.0001
Gilts	.09332	.10184	.97893	1.0000	.9999	.9999
	.6238	.5623	.0001	0.0000	.0001	.0001
Boars	.09272	.10264	.97906	.9999	1.0000	.9999
	.6260	.5894	.0001	.0001	0.0000	.0001
Market	.09285	.10224	.97883	.9999	.9999	1.0000
	.6255	.5909	.0001	.0001	.0001	0.0000

Observed Significance Level listed below the correlation coefficients

In order for the model to generate multivariate random normal deviates necessary for stochastic prices, an upper triangular "A" matrix which when multiplied by its transpose gives the original covariance matrix (Table 9) must be determined. Table 11 shows this upper triangular A matrix. This matrix is the input necessary for FLIPSIM simulations.

Management Strategies

After the 27 hog breeding schemes are stochastically ranked, the most and least efficient strategies are subjected to several other simulations to determine the effect of management variables on NPV and income.

Facilities Management

The litters per farrowing sow per year in the base study is assumed 2.42. This number requires superb management but is attainable with the facilities and per the schedule previously described. Several records surveys show that producers are not obtaining this much utilization of sows and facilities. To study the impact of facilities utilization, the operation is simulated assuming 2.25 and 2.1 litters per farrowing sow per year. Under the assumption of 87% conception the three facilities utilization scenarios yield 2.10, 1.96 and 1.83 litters per year per female in the breeding herd, respectively. This is more easily managed and corresponds with survey data.

Farrowing Management

Another area of management influence is the size and variance associated with number of pigs weaned. Experiment station data suggest that the distribution be normal. However, one study shows the distribution

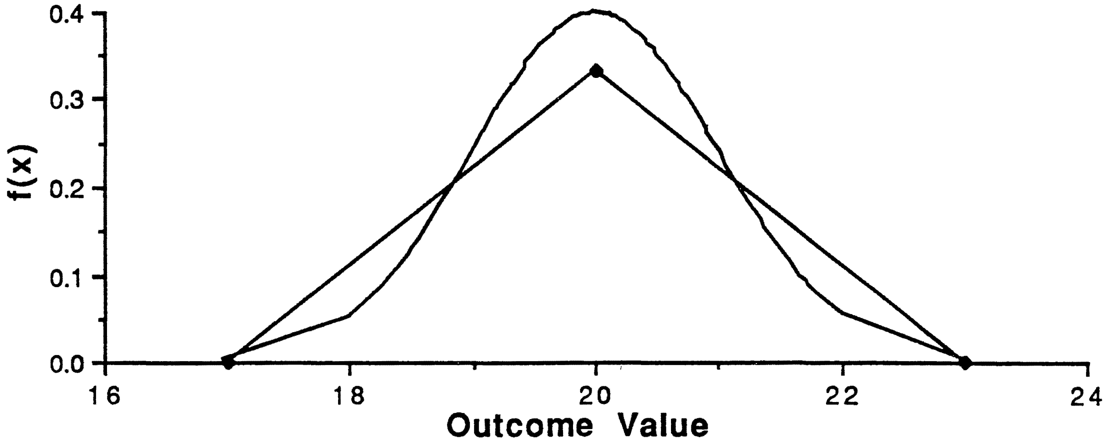
TABLE 11

UPPER TRIANGULAR A MATRIX

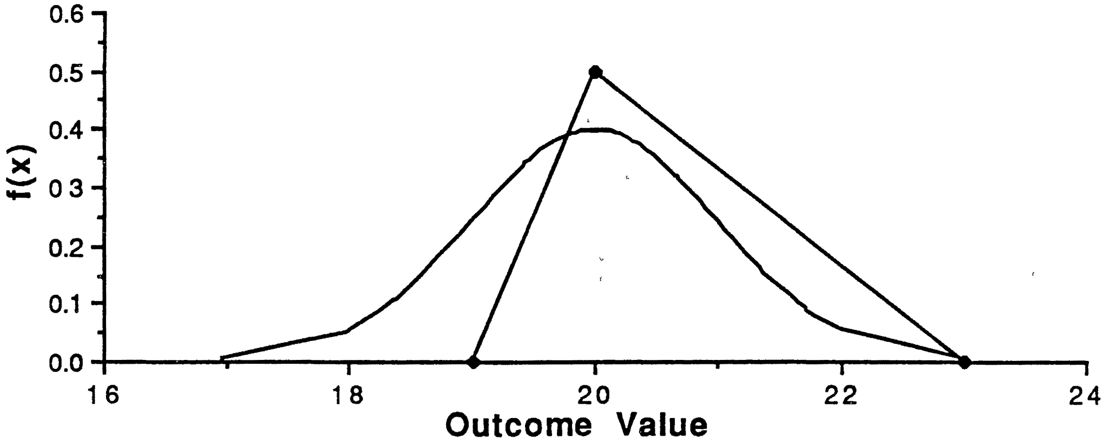
	Sorghum	Hog Concentrate	Sows	Gilts	Boars	Market Hogs
Sorghum	.1030	-.0189	.0129	.0151	-.0026	.0099
Hog Concentrate-		.1959	-.0632	-.0297	.0154	.0214
Sows			.2085	.0083	.0457	1.0218
Gilts				.0036	.0016	.9798
Boars					.0039	.7070
Market Hogs						1.0889

associated with number of pigs weaned per sow to be skewed (Wilson and Eidman). When looking at managerial rather than genetic impacts on production, other distributions might be valid. It could be argued that producers who farrow hogs of the same genetic background will have the same number of live births, ceteris paribus. The number of those pigs weaned may be greatly influenced by the degree of supervision at farrowing and throughout the lactation phase of production. Facilities may also influence the number of pigs weaned.

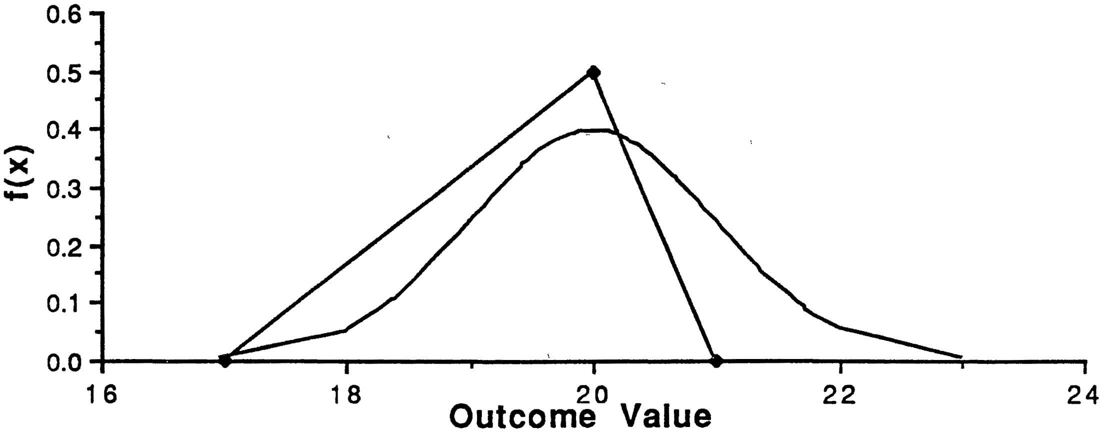
To model skewness of number of pigs weaned, a triangular distribution was assumed in lieu of a normal. The triangular distribution is chosen for its simplicity and flexibility. To simulate poor farrowing management (designated TRI-3) where the producer might have the same mode but is unable to wean the larger litters negative skewness is simulated. The mode of the triangular distribution is the mean of the normal; the minimum is minus three standard errors; the maximum is plus one standard error. This gives a distribution with negative skewness and a mean lower than the mode. To model superior farrowing management (designated TRI+3) where the producer is able to save more live pigs to weaning, positive skewness is simulated. The mode of the triangular distribution is the mean of the normal; the minimum is minus one standard error; the maximum is plus three standard errors. This gives a distribution with positive skewness and a mean greater than the mode. The TRI=3 simulation is a triangular meant to reflect a normal by setting its mode equal to the mean and its minimum and maximum equal to plus and minus three standard deviations, respectively. Figure 14 illustrates the triangular distributions as used here. The underlying normal distribution is imbedded for comparison purposes.



A. Good Management (TRI=3)



B. Excellent Management (TRI+3)



C. Inefficient Management (TRI-3)

Figure 14. Distributions Used to Model Farrowing Management.

Feed Management

The feed efficiency parameter reported in the extension research reports for various breeding schemes is more efficient than usually encountered in commercial pork production. This could be due to feed spillage, to poor equipment or feed handling, or to rodent damage. To account this divergence, a 10% waste factor was added into the base simulations feed efficiency. Several other simulations, assuming waste of 7.5%, 5% and 2.5%were made, to determine the value of reducing this waste. This should give producers an idea of how much spillage effects income and also the value of increased feed efficiency.

Financial Management

The base simulation is performed assuming a 50% debt to asset ratio. Different managers would have different financial resources and philosophies. Finance theory indicates that leverage, the percent of debt used in production, increases both the expected return and the variance about that return. Two additional debt to asset ratios, 30% and 70%, are modelled to simulate the impact of financial arrangements on production.

Income Volatility Analysis

Risk is often measured by the standard deviation associated with an outcome variable. The higher the standard deviation, the greater the risk; and vice versa. The volatility of income of a producer is a function of the volatility of the business marketing and production practices. The volatility due to price fluctuations is well documented and readily observed. The volatility due to production attainments is not so well documented nor readily observed.

The simulation model is subjected to a number of scenarios designed to estimate the volatility due to any one variable or group of variables. By holding certain stochastic variables constant during the simulation an approximation of the effect of those variables can be made. The results of these simulations are analyzed in light of several pertinent theorems regarding variance. This information can be used to determine where management energy should be placed to both increase income and decrease its variance. NPV and Average Annual Taxable Income (Income) are the measures used in this section of the study.

The production variables of reproductive efficiency and feed conversion are independently distributed. Therefore, to eliminate the variance of those parameters the standard error in the model is set equal to zero. Both livestock and feed price variables are correlated in the model causing more complexity to be necessary in eliminating any one source of variation. To eliminate all price variance, the upper triangular A matrix has all of its elements set equal to zero. When the variance of only one price, i.e. sorghum, is set equal to zero its standard error and all covariances associated with that variable must also be set equal to zero. The covariance equals E{[x - E(x)][y - E(y)]}. If any one variable is fixed, covariance no longer exists since E(x) = x and thus [x - E(x)] = 0 yielding a covariance of zero. To analyze only one price variable at a time, the entire row associated with that variable in the upper triangular A matrix is set equal to zero. When the model is simulated as if the price variables are uncorrelated, the standard errors remain in the upper triangular matrix but the remainder of the rows are set equal to zero.

FLIPSIM is constructed of accounting, rather than econometric, equations. NPV and Income are essentially the result of a complex equation.

Unpublished work by Massey and Williams using a much simpler simulation model found returns to pork production to be described by the equation:

$$\text{Annual Returns} = a_1PW + a_2P - a_3W - a_4FC - a_5FWC - \text{fixed costs.} \qquad (38)$$

where: P = livestock market price,

W = litter size

F = feed price and

C = feed conversion.

The coefficients, a_i, would differ in this model from the previous research. The relationships between variables are expected to be similar. Return is a function of summation of products between P, W, F and C. Theorems 1 and 2 from the statistical theory section indicate that when a variable Y equals a linear combination of the random variables, $(X_1, X_2, \ldots, X_n)$, where the random variables, X_i, may be a product of variables such as P and W, the mean and variance can be estimated. Thus $E(X_i) = E(PW) = E(P)E(W) + Cov(P,W)$. $Cov(P,W)$ will equal zero if no correlation exists between the two variables, as in this study. If equation 38 adequately approximates the relationships in this model no covariance exists between any of the products of interest and the expected value of returns will be an expected value of the sum of products.

Since livestock prices are near perfectly correlated, a single variable P can represent the four livestock prices used. Sorghum and hog concentrate prices, not highly correlated, are not as well represented by a single variable F, but for this preliminary analysis may be sufficient. When theorem 3 is incorporated into the discussion to account for any covariance occurring across summed variables, the covariance is found to be zero. Thus the expected return is simply the summation of expected products. Holding one variable constant should have little, if any, effect on mean NPV and Income.

Holding one variable constant will have significant effect on the variance of NPV and Income. The magnitude of the effect will depend on the magnitude of the variance of the random variable held constant and the magnitude of the coefficient associated with that variable in any product of variables. Since the actual coefficients are unknown for the pork production unit modeled, the importance of each random variable cannot be estimated. The actual simulations will be necessary to answer this question. The simulations will show how much NPV and Income standard deviation is reduced when certain variables are held constant. The comparison of these results will give the relative importance of production and marketing variables in determining income volatility.

CHAPTER IV

RESULTS

The modified version of FLIPSIM V is used to rank the 27 breeding schemes possible using various combinations of Hampshire, Yorkshire and Duroc hogs. Litter size appears to be the most important production trait when considering both mean income and income variability. Those schemes with the highest number of pigs weaned consistently fare better economically than those with fewer pigs weaned. Extremely good reproductive efficiency can counteract the effects of lackluster feeding efficiency. The scheme characterized by the highest litter size (DxHY) was ranked number one while the scheme with the best feed efficiency (HxDY) was ranked number three, using stochastic dominance analysis.

Various management strategies are also evaluated on the simulated swine production unit. Such questions as the value of 1) more intensive facilities utilization, 2) reducing variance in litter size by more closely supervising farrowing, 3) controlling feed waste and 4) the impact of debt are addressed. Managers can use this information to know where to best put their efforts in improvements.

A third aspect of the analysis addresses the relative contribution of production factors and marketing factors in pork producers' income volatility. Managers have several options when trying to level out income. Production variability interacts with economic factors to cause wide swings in income.

Different management responses are required to control different sources of volatility.

This chapter addresses these considerations in the order mentioned.

Breeding Schemes

Overview of the Results

The producer's after tax net present value (NPV), minimum, maximum, standard deviation, skewness and internal rate of return (IRR) for each of the 27 different breeding schemes are given in Table 12. NPV is defined as the sum of the discounted values of each year's change in net worth plus family living withdrawals. Family living withdrawals are a function of income and are included in cash costs. The IRR is the discount rate which equates the present value of cash inflows to the present value of cash costs. As listed each time in this research IRR refers only to the internal rate of return at the end of the last solvent year. It does not report the IRR for the entire ten-year period. They are given to facilitate the discussion of breeding schemes and management strategies.

All of the breeding schemes modeled remained solvent the entire ten year simulation period although some experienced extremely low or negative internal rates of return. The DxHY scheme possesses the highest mean NPV at $282,328 and highest tenth year IRR at 17%. The HxH scheme possesses the lowest mean NPV and IRR at $60,869 and -14%, respectively. The DxD, HxH and HxD schemes net negative IRR, while the DxH scheme yields a zero IRR. All the schemes show a slight positive skewness in NPV.

Insolvency occurs when the firm's equity to asset ratio is less than .25. Despite negative or low IRR on some schemes in some years, no firms are declared insolvent during the ten-year simulations. It might be expected that

TABLE 12

STOCHASTIC OUTPUT FROM THE SIMULATION OF 27 SWINE BREEDING SCHEMES

Breeding	Net Present Value (10 years)			Standard	Skew-	Internal Rate
Scheme	Mean	Minimum	Maximum	Deviation	ness	of Return
	--------------dollars--------------					
			Purebreds			
DxD	65,869	45,891	93,306	9,134	.16	-.12
HxH	60,426	40,924	86,798	9,217	.16	-.14
YxY	200,361	165,606	260,084	18,547	.74	.10
		Two-Breed Terminal Crosses				
DxH	124,124	96,714	166,139	13,091	.66	.00
DxY	216,816	180,142	277,041	19,421	.64	.11
HxD	97,768	75,772	134,689	11,526	.55	-.05
HxY	204,315	168,815	264,023	18,891	.75	.10
YxD	184,361	152,512	244,830	17,124	.93	.08
YxH	136,761	108,463	181,052	13,778	.72	.02
		Three-Breed Terminal Crosses				
DxYH	265,946	223,117	323,118	20,920	.17	.16
HxYD	254,336	212,809	311,911	20,600	.28	.15
YxHD	195,689	161,970	255,666	18,192	.78	.09
HxDY	261,372	219,269	318,656	20,919	.22	.15
YxDH	202,905	168,300	262,853	18,497	.74	.10
DxHY	282,328	242,576	338,616	20,143	.19	.17
		Two-Breed Terminal Backcrosses				
DxDH	216,127	179,760	276,516	19,406	.66	.11
DxHD	208,980	173,540	269,163	19,121	.75	.11
DxDY	193,885	159,934	253,248	18,145	.78	.09
DxYD	187,035	154,276	246,879	17,463	.86	.08
HxDH	140,721	112,918	185,595	13,758	.73	.03
HxHD	135,196	107,619	179,011	13,588	.72	.02
HxHY	173,516	142,651	233,279	16,792	.97	.07
HxYH	160,459	130,712	219,933	15,876	1.02	.05
YxDY	217,350	180,915	277,774	19,419	.64	.11
YxYD	210,464	174,992	270,693	19,117	.72	.11
YxHY	208,269	172,845	268,366	19,104	.73	.10
YxYH	193,897	160,226	253,608	18,117	.80	.09

Note: D = Duroc, Y = Yorkshire, H = Hampshire some firms would have been declared insolvent at some time during the simulation iterations and various economic conditions. The early 1980's saw many agricultural producers exit agriculture due to financial difficulties. The absence of observed bankruptcies in this research is attributable to several factors. First, the simulated production unit is one which is already established and in full production. Thus, regular inflows and outflows of cash are occurring. Massey, et.al. detail the difficulty of the first two years of starting a 140 sow farrow-to-finish confinement operation as modelled in this research. Since these first two years are assumed passed, the cash flow problems inherent in start up do not interact to model insolvency conditions.

Second, research by Futrell shows that though there were periods of negative profits for farrow-to-finish pork production from 1979 to 1988 (see Figure 1), these periods were short and not severe. If a producer has sufficient cash reserves and/or a lender willing to work with him for short periods of time, the periods of negative profit could have been weathered. The producer in this simulation is assumed to have access to operating loans when needed and also does not invest profits from previous years in non-liquid investments. The sum of the previous year's profits are in liquid, interest bearing accounts accessible for use when needed. The lack of expansion may be the key reason that few insolvencies are encountered. When previous years' profits are used for expansion in non-liquid asset accumulation such as land and buildings, the probability of insolvency may greatly increase.

Third, the production standards of the simulation assume excellent facilities management. The number of litters per sow per year is 2.42. This can be compared to an average of approximately 2.1 litters per sow per year reported by many commercial operations. The impact of managing the operation under various assumptions are discussed in more detail in a later section.

Though no insolvencies occur in the simulations, those producers using schemes which report negative or low internal rates of return may have chosen to cease production. That the production units are not declared insolvent during the simulation implies that the operator survived on previous wealth and was content to receive low returns on investment.

Rankings of Breeding Schemes

Various methods of ranking the breeding schemes were employed. The mean-variance (EV) method of ranking is not discriminant enough to completely rank the breedings schemes. Those schemes with the highest mean NPV also tend to have the highest standard deviation. Results of the EV analysis are detailed in Table 13. No other ranking can be ascertained. DxHY is shown to be dominant to only three schemes. The minimum NPV observed during the ten year simulation period for DxHY is higher than the maximum NPV of every scheme except DxYH, HxYD and HxDY - those which EV analysis indicates are economically inefficient compared to the DxHY scheme. Nevertheless, using the EV criteria, the DxHY scheme can not be determined to be preferred to those schemes with maximum NPVs below its minimum NPV.

In addition to its lack of discriminatory power, EV analysis lacks sufficient theoretical grounds to be valid. EV analysis assumes normality in the results (hence only the first two moments are required) but the NPV's all exhibit positive skewness (see Table 12).

Evaluating alternative investments by the coefficient of variation (CV) is a common method used in finance. CV ranking assumes only that the lowest variation per dollar of expected NPV is desirable. CV analysis yields a

TABLE 13

MEAN-VARIANCE ORDERING OF 27 HOG BREEDING SCHEMES

Dominant Scheme	Dominated Scheme(s)
DxD	HxH
DxHY	DxYH, HxYD and HxDY
YxDH	YxY
HxDH	YxH
YxDY	DxY
YxYD	DxHD
YxYH	DxDY

complete ordering of the breeding schemes and is reported in Table 14. DxHY is ranked number one with other three-breed terminal crosses having Yorkshires in the maternal position following. Two-breed terminal and two-breed terminal backcrosses are mixed in the center of the ranking. Purebred Hampshires and Durocs are ranked lowest. This ranking needs to be considered with the realization that in this research purebred hog producers receive slaughter hog price for all of their animals. Typically, purebred hog producers raise purebreds for sale as breeding animals at a premium above slaughter price. Therefore this research may underestimate purebred hog producers' income.

To account for the non-normal distribution on the NPV and to take into account the risk attitudes of producers, stochastic efficiency criteria are used. Table 15 lists the rankings of the breeding schemes for first degree stochastic dominance (FSD). FSD, though the least discriminating of the criteria discussed in the theory chapter, is sufficiently discriminating to order all but two of the schemes. Only the YxYH and DxDY schemes are unable to be ordered using FSD. This ranking of schemes would be appropriate for all decision makers who prefer more wealth to less wealth regardless of their risk attitudes.

As in CV analysis, the DxHY scheme ranks first; the HxH scheme last. The first eight schemes and the last four schemes are identical when using FSD or CV analysis. The middle rankings differ with no apparent pattern.

SSD, which is appropriate for producers who are risk averse and prefer more wealth to less wealth, is not able to order the YxYH and DxDY schemes either. All other SSD rankings correspond to FSD ranking. Empirically, the algorithm used considers only the range $0 < r_a < 99$. Several intervals of risk aversion are tested using GSD, but again without the YxYH and DxDY schemes being ordered. McCarl presents a method of determining which risk aversion

TABLE 14

COEFFICIENT OF VARIATION ORDERING OF 27 HOG BREEDING SCHEMES

Rank	Breeding Scheme	Coefficient of Variation of NPV
1	DxHY	7.14
2	DxYH	7.87
3	HxDY	8.00
4	HxYD	8.10
5	YxDY	8.93
6	DxY	8.96
7	DxDH	8.98
8	YxYD	9.08
9	YxDH	9.12
10	DxHD	9.15
11	YxHY	9.17
12	HxY	9.25
13	YxY	9.26
14	YxD	9.29
15	YxHD	9.30
16	DxYD	9.33
17	YxYH	9.34
18	DxDY	9.36
19	HxHY	9.68
20	HxDH	9.78
21	HxYH	9.89
22	HxHD	10.05
23	YxH	10.08
24	DxH	10.55
25	HxD	11.79
26	DxD	13.87
27	HxH	15.25

TABLE 15

FIRST DEGREE STOCHASTIC DOMINANCE ORDERING OF 27 HOG BREEDING SCHEMES

Rank	Breeding Scheme	Number of Pigs Weaned per Sow	Pounds of gain per pound of feed
1	DxHY	21.77	.3292
2	DxYH	21.36	.3286
3	HxDY	21.09	.3319
4	HxYD	20.93	.3310
5	YxDY	20.63	.3155
6	DxY	20.32	.3217
7	DxDH	20.41	.3194
8	YxYD	20.47	.3146
9	DxHD	20.21	.3192
10	YxHY	20.16	.3198
11	HxY	19.56	.3310
12	YxDH	20.30	.3140
13	YxY	19.74	.3240
14	YxHD	20.09	.3137
15	YxYH[a]	19.76	.3191
16	DxDY[a]	19.50	.3251
17	DxYD	19.35	.3242
18	YxD	19.57	.3171
19	HxHY	19.00	.3222
20	HxYH	18.60	.3215
21	HxDH	18.30	.3122
22	YxH	17.56	.3278
23	HxHD	18.10	.3120
24	DxH	17.45	.3174
25	HxD	16.39	.3160
26	DxD	15.06	.3000
27	HxH	14.51	.3070

[a] indeterminate

intervals would cause decision makers to make a distinction. It is not performed due to the limited benefit it would have in this analysis.

The GSD concept is useful in determining the marginal value of a dominant scheme relative to a dominated scheme. The value of information is dependent on risk attitudes Mjelde and Cochran show that by lowering the dominant option there comes a threshold (lower bound) at which one person who conforms to the risk attitude restrictions can no longer choose between the efficient and inefficient alternatives. By continuing to lower the dominant option, there exists a second threshold (upper bound) at which every person who conforms to the risk attitude restrictions believes the previously subordinate option becomes dominant. These upper and lower bounds are recognized as the value of the information regarding which alternative is dominant.

The bounds can also give insight into the amount a producer would be willing to pay to move to the dominant option. The upper and lower bounds for the 27 breeding schemes are listed in Table 16 under the risk attitude assumption of $-.000295 < r_a < +.000295$. This range closely corresponds to the range which Eidman and Wilson reported to encompass the majority of pork producers.

Their interpretation is as follows. If a group of producers were currently producing with the DxYH scheme and believed the present value cost of adoption of the DxHY scheme to be less than $15,027, all of the producers would opt for the change. If the present value cost of adaption were greater than or equal to $15,027, at least one producer, the most risk preferring in this case, would choose to continue operating as is. If the present value cost of adoption were greater than $18,904 all producers would choose to remain with the inferior production practice. Every breeding scheme can be analyzed in the same method described above.

TABLE 16

UPPER AND LOWER BOUNDS ON THE WILLINGNESS TO PAY TO ADAPT THE DXHY HOG BREEDING SCHEME FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Rank	Breeding Scheme	Lower Bound	Upper Bound
		dollars	dollars
2	DxYH	15,027	18,903
3	HxDY	19,195	22,816
4	HxYD	25,880	29,156
5	YxDY	60,284	68,533
6	DxY	60,924	69,081
7	DxDH	61,430	69,696
8	YxYD	66,620	75,853
9	DxHD	67,828	77,249
10	YxHY	68,524	69,081
11	HxY	72,115	82,415
12	YxDH	73,551	83,600
13	YxY	75,690	86,100
14	YxHD	80,308	90,971
15	YxYH	81,796	92,780
16	DxDY	81,703	92,751
17	DxYD	87,812	100,302
18	YxD	90,032	103,480
19	HxHY	100,088	114,325
20	HxYH	112,241	129,317
21	HxDH	130,419	152,636
22	YxH	134,432	156,442
23	HxHD	135,809	158,403
24	DxH	146,718	170,443
25	HxD	169,463	203,581
26	DxD	199,593	243,996
27	HxH	204,947	250,163

The superiority of the DxHY breeding scheme conforms to prior expectations. First, a three breed terminal cross is expected to dominate since it exhibits the greatest heterosis of all the schemes modelled. Second, the Yorkshire breed is expected to be in the maternal position due to its maternal qualities. The Yorkshire is generally recognized as a superior sow.

Furthermore the results conform, in general, to prior research on breeding systems. McLaren, et al. found the Duroc x (Yorkshire, Landrace, Spotted) four breed rotaterminal cross to be the most efficient crossbreeding system. Similarities are the Duroc in the sole paternal position and the Yorkshire, crossed with other breeds, in the maternal position. McLaren, et al. include the Landrace and Spot breeds which this research doesn't; this research includes the Hampshire breed which McLaren, et al do not. The presence of a rotational system, rather than a terminal, in the maternal position may be due to the industry-wide orientation of McLaren, et al. The maintenance of side herds on a producer level as modelled in this research is admittedly cumbersome for management. The increase in production volatility associated with a rotational system would theoretically preclude it from being the stochastically dominant scheme in a producer level study. Wilson and Johnson (1981b) rank the DxHY scheme highest in production efficiency but when all matings needed to support the system are included, ranked the YxDY scheme the most efficient.

The importance of reproductive efficiency in determining mean NPV (Note: a necessary condition for FSD dominance of A over B is $\mu_a \geq \mu_b$) is seen by examining Figure 15. The dominant schemes have the greatest number of pigs weaned per year. In fact, litter size ordering closely corresponds to FSD ordering. The extremities of the ordering are precise. Only in the middle of the ordering does feed efficiency interact strongly enough to preclude an accurate

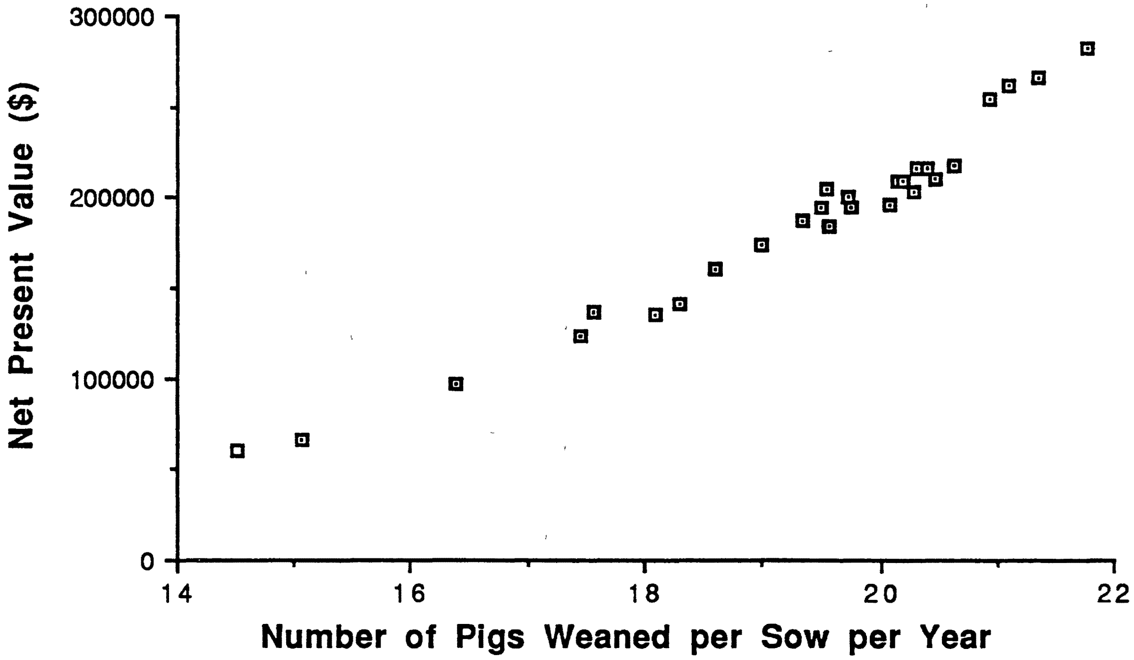


Figure 15. Effect of Litter Size on Net Present Value for a 140 Sow Farrow-to-Finish Confinement System

ordering by breeding efficiency alone. Conversely, feed efficiency is of less help in approximating FSD ordering as is illustrated in Figure 16. Number of pigs weaned is the strongest production trait in determining profitability. This agrees with the findings of Edwards, van der Sluis and Stevermyer. They found reproductive performance to be a key management area for maintaining or improving profits in swine production.

The importance of the breeding herd composition is revealed in the breeding scheme rankings. Several schemes had the exact same terminal hog composition yet were ranked much differently. For example, the three breed terminal cross using Duroc boars and Hampshire/Yorkshire females can be composed in two ways. The side herds necessary to produce Hampshire/Yorkshire females can consist of a small purebred Hampshire herd and a larger, but relatively small, herd of Hampshire females being bred to Yorkshire boars (scheme DxYH). Alternatively, the side herds could consist of a small purebred Yorkshire herd and a larger, but small, herd of Yorkshire females being bred to Hampshire boars (scheme DxHY). Both of the above strategies would produce Hampshire/Yorkshire females for the largest portion of the breeding herd which produces the terminal market hogs. However, scheme DxHY clearly dominates scheme DxYH. The mean NPV of the two schemes differs by $16,382. Producers who are producing identical market hogs may have different profits simply because they utilize different combinations of breeding stock. All three breed terminal crosses and two breed terminal backcrosses exhibit the same phenomenon to some degree. The greatest difference is reported between the DxHY and DxYH schemes, whose NPV differ by $16,382; the smallest difference, between the HxDH and HxHD schemes, whose NPV differ by $5,525.

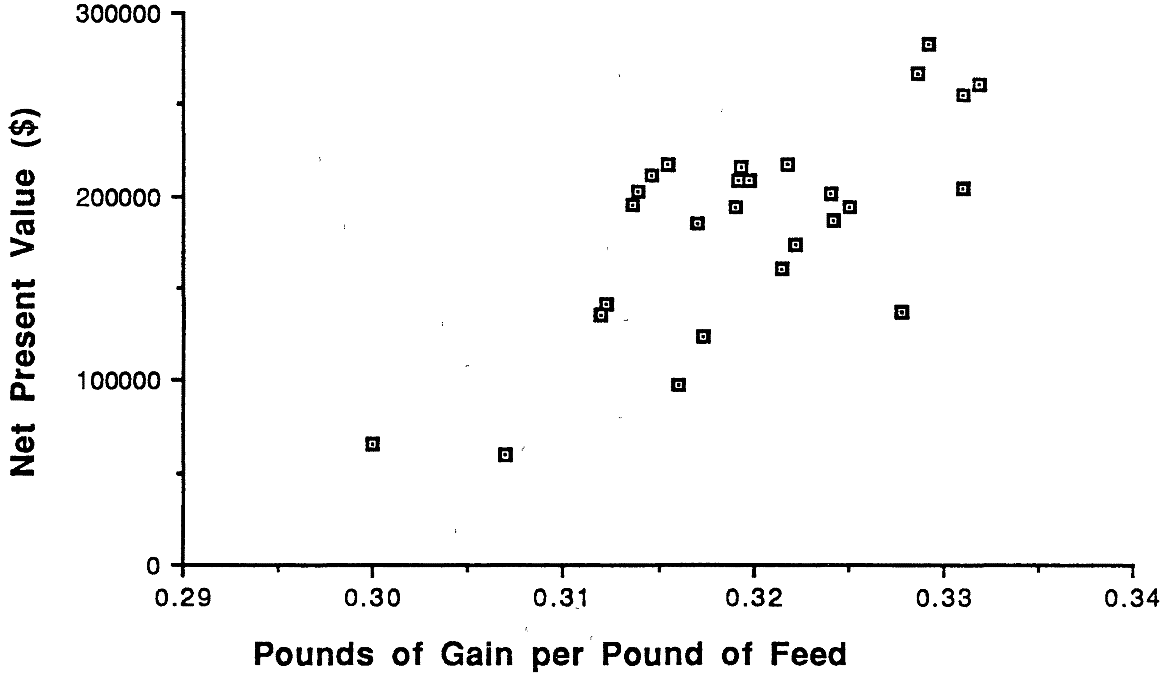


Figure 16. Effect of Feed Efficiency on Net Present Value for a 140 Sow Farrow-to-Finish Confinement System

If the replacement gilts were purchased rather than being raised in side herds, the peculiarities discussed above would not exist. The ordering of schemes might change if the purchase price of replacement breeding stock were not equal across all breeds. Furthermore, the results in commercial production might change since receiving animals increases the chance of introducing disease into a herd. This may increase the medical costs and the probability of economic loss or failure. DxHY, the dominant scheme, is simulated with no replacement gilts raised but all purchased. The whole herd litter size increases from 21.77 to 22.32 since all the farrowing females are now DxHY. The pounds of gain per pound of feed decreases from .3292 to .3288. The result is a larger number of market hogs sold with slightly more feed consumed per animal. Replacement gilts are assumed purchased at 230 pounds and fed to 275 pounds for breeding. The replacement gilt purchase price is set at $0. The comparative statistics are shown in Table 17. Average Annual Taxable Income (Income) as used in this research is the return to the 1) operating capital, 2) the investment in land, facilities and breeding stock and 3) unpaid labor and management. Family living expenses and income tax due must come from this income.

The differences in the two simulations indicates the value of the purchased breeding stock. The operation modelled experiences an Income gain of $16,124 by purchasing replacement gilts, assuming the price is $0. Therefore, the producer can afford to pay an average of $131.09 per gilt if the same number of gilts are added to the breeding herd as in the base simulation (123 gilts per year). This equals $57.00 per hundredweight if they are purchased at 230 pounds. The ten year average price for market hogs is $46.56. The $10.44 difference per hundredweight is the premium the producer can afford to pay for breeding-quality market gilts. The $131.09 average price

TABLE 17

THE IMPACT OF PURCHASING VERSUS RAISING REPLACEMENT GILTS FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Variable	Raise Replacements	Purchase Replacements
Number of Pigs Weaned Per Sow Per Year		
Mean	21.77	22.32
Standard Deviation	1.081	1.081
Pounds of Gain per Pound of Feed		
Mean	.3292	.3288
Standard Deviation	.0048	.0048
Net Present Value		
Mean ($)	282,330	341,614
Standard Deviation ($)	20,143	19,021
Coefficient of Variation	7.13	5.57
Average Annual Taxable Income		
Mean ($)	100,528	116,652
Standard Deviation ($)	3,679	3,788
Coefficient of Variation	3.66	3.25
Internal Rate of Return		
Mean	.17	.20
Standard Deviation	.01	.01

should include the purchase price, a disease risk discount and any costs associated with acquisition.

Management Strategies

Facilities Management

To analyze the effect of facilities utilization on producer income, the number of litters per farrowing sow per year are reduced from 2.42 to 2.25 and 2.1. These result in 1.96 and 1.83 litters per female in the breeding herd per year and more closely resemble production standards reported by farm business surveys (see Table 1). The results on NPV, Income and IRR for the most and least stochastically efficient breeding schemes (DxHY and HxH) are given in Table 18.

The 2.25 litters per sow per year DxHY producer is sacrificing a average annual taxable income of $12,051. This is $86.08 per sow for use in comparing with similar operations having different breeding herd size. The Income from the 2.1 litters per sow per year DxHY producer sacrifices $22,456; or $160.40 per sow. For each .1 increase in the number of litters per sow per year Income will increase an average of $7,017 for the 140 DxHY sow herd. Figure 17 shows that the effect of facilities utilization is less stark when raising less efficient breeding schemes. The least efficient scheme (HxH) shows the value of increasing production by .1 litters per sow per year to be $4,091 for the 140 sow operation.

The change in IRR resulting from various number of litters per sow per year is significant. In 1988, the producer managing 2.42 litters per sow per year receives 16.8% IRR while the producer managing only 2.1 receives only 7.3%. When an inefficient scheme such as HxH is utilized the change in IRR is from -14.0% to -27.9%. The more efficient breeding schemes and most intensive

TABLE 18

THE IMPACT OF FACILITY UTILIZATION ON ECONOMIC MEASURES FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Litters Per Sow Per Year	2.42	2.25	2.1
	DxHY		
Pigs Weaned Per Sow Per Year			
Mean	21.77	20.24	18.89
Standard Deviation	1.081	1.005	.938
Net Present Value			
Mean ($)	282,330	224,921	177,933
Standard Deviation ($)	20,143	19,398	15,976
Coefficient of Variation	7.13	8.62	8.98
Average Annual Taxable Income			
Mean ($)	100,528	88,477	78,072
Standard Deviation ($)	3,679	3,459	3,137
Coefficient of Variation	3.66	3.91	4.02
Internal Rate of Return			
Mean	.168	.121	.073
Standard Deviation	.014	.016	.017
Coefficient of Variation	8.33	13.22	23.29
	HxH		
Pigs Weaned Per Sow Per Year			
Mean	14.51	13.49	12.59
Standard Deviation	1.081	1.005	.938
Net Present Value			
Mean ($)	60,426	46,644	35,634
Standard Deviation ($)	9,217	7,991	7,022
Coefficient of Variation	15.25	17.13	19.71
Average Annual Taxable Income			
Mean ($)	41,372	34,496	28,280
Standard Deviation ($)	2,789	2,629	2,428
Coefficient of Variation	6.74	7.62	8.59
Internal Rate of Return			
Mean	-.140	-.179	-.279
Standard Deviation	.028	.031	.307
Coefficient of Variation	-20.00	-17.32	-110.04

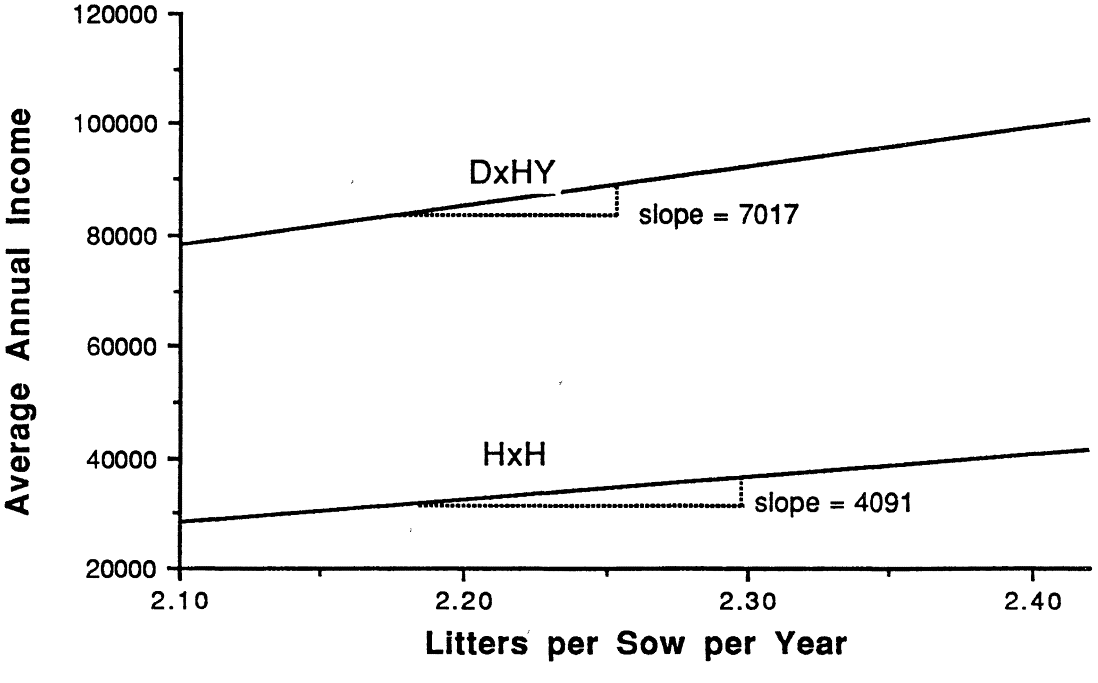


Figure 17. The Effect of Litters per Sow per Year on Income for a 140 Sow Farrow-to-Finish Confinement System

facilities utilization yield both higher mean and lower standard deviation of IRR. This occurs despite lower standard deviations on the number of pigs weaned per year (a function of litters per sow per year) used for less intensive facilities utilization operations.

The standard deviation on NPV and Income increase as more litters per sow per year are obtained but not as fast as the mean of NPV and Income rise. The CV of NPV and Income both decrease with greater efficiency in managing the sows to produce more litters per year. The lower CVs indicate less risk when risk is measured by the standard deviation per dollar. Reproductive merit of the breeding stock and managerial efficiency lower risk in pork production.

Using the willingness to pay concept, if for the DxHY producer the cost of more intensely utilizing facilities from 2.25 to 2.42 over the ten year period lies between $53,116 and $60,594, at least one producer and all producers, respectively, will opt not to adopt. For an increase from 2.1 to 2.42 the cost could be between $94,535 and $111,239 with the same results.

Litter Size

Another management impact studied is the retention of live pigs until weaning. The base simulation (used to rank breeding schemes) assumed a normal distribution on the number of pigs weaned. To attempt to model the impact of farrowing management and facilities on the number of pigs weaned, the normal distribution is exchanged for a triangular distribution. The TRI=3 simulation is a triangular meant to reflect a normal by setting its mode equal to the mean and its minimum and maximum equal to plus and minus three standard errors, respectively. The TRI-3 simulation models inefficient managers who might have the same mode but a distribution skewed to the left due to inability to save large litters until weaning. Effectively, this insures that the number of pigs weaned per sow per year does not exceed the mean plus one standard error. The TRI+3 simulation models excellent managers who might have results just the opposite--positive skewness and the same mode. This insures that the number of pigs weaned per sow per year does not fall below the mean minus one standard error. Though the modes are identical, the means differ due to the skewness of the distribution. These possibilities are modelled using the DxHY and HxH breeding schemes. Pertinent statistics describing the results are listed in Table 19.

The TRI=3 simulation corresponds closely with the normal distribution in the mean simulated litter size, NPV, Income, and IRR. The standard deviation in litter size under the triangular simulation is less than under the normal simulation. This may account for the TRI=3 NPV standard deviation being less than the normal NPV standard deviation. The following analysis compares alternative management strategies to the TRI=3 results so that a triangular simulation is compared to a triangular simulation.

The inefficient 140 sow farrow-to-finish DxHY producer, modelled by TRI-3, has a mean NPV $19,593 less than the TRI=3 producer. On a per sow basis the poor producer accrues $139.95 less in NPV over the ten year period. Income decreases by $3,953 or $28.24 per sow. The IRR is 15% for the TRI-3 producer compared to 17% for the TRI=3 producer. Risk, as measured by the standard deviation, is greater for the TRI=3 producer. This may be a result of the way the triangular distribution is modelled. The TRI-3 inefficient producer has a smaller range (four standard errors) on the number of pigs weaned per sow per year than the TRI=3 producer (six standard errors). This may or may not be the case in commercial production. An inefficient producer may experience a lower mean number of pigs weaned per year, negative skewness and a range more near TRI=3 type producers.

TABLE 19

THE IMPACT OF NUMBER OF PIGS WEANED ON ECONOMIC MEASURES FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Plan	TRI=3	TRI-3	TRI+3	Normal
		DxHY		
Pigs Weaned Per Sow Per Year				
Mean	21.77	21.27	22.35	21.77
Standard Deviation	.24	.11	.20	.32
Net Present Value				
Mean ($)	283,263	263,670	304,900	282,330
Standard Deviation ($)	17,976	16,455	16,946	20,143
Coefficient of Variation	6.35	6.24	5.56	7.13
Average Annual Taxable Income				
Mean ($)	100,708	96,755	105,276	100,528
Standard Deviation ($)	3,215	2,667	3,054	3,679
Coefficient of Variation	3.19	2.76	2.90	3.66
Internal Rate of Return				
Mean	.17	.15	.18	.17
Standard Deviation	.01	.01	.01	.01
		HxH		
Pigs Weaned Per Sow Per Year				
Mean	14.49	13.99	15.07	14.51
Standard Deviation	.24	.11	.20	.32
Net Present Value				
Mean ($)	60,420	51,913	69,549	60,426
Standard Deviation ($)	7,802	6,770	7,282	9,217
Coefficient of Variation	12.91	13.04	10.47	15.25
Average Annual Taxable Income				
Mean ($)	41,418	38,123	45,280	41,372
Standard Deviation ($)	2,332	1,757	2,110	2,789
Coefficient of Variation	5.63	4.61	4.66	6.74
Internal Rate of Return				
Mean	-.14	-.16	-.11	-.14
Standard Deviation	.02	.02	.02	.03

The excellent 140 sow farrow-to-finish DxHY producer, modelled by TRI+3, has a mean NPV $21,637 more than the TRI=3 producer. On a per sow basis the excellent producer accrues $154.55 more in NPV over the ten year period. Income increases by $4,568; or $32.63 per sow. IRR also increases from 17% to 18% for better farrowing management.

For the HxH producer, the poor farrowing management reduces NPV by $8,507; or $60.76 per sow. Excellent farrowing management can increase NPV $9,129 over TRI=3; or $65.21 on a per sow basis.

Those producers utilizing superior breeding schemes have the greatest incentive to improve farrowing management and facilities. The same relative improvement yields a greater return for dominant breeding schemes than for inefficient breeding schemes. Producers with efficient breeds would fare best by concentrating on management and facilities improvement while producers with inefficient breeds might fare best by changing their breeding herd to a more efficient breed combination. The decision of whether to concentrate on management or breeding scheme depends on which breeding scheme is being used.

Using the willingness to pay concept, all DxHY producers would choose to improve their farrowing management and facilities to obtain TRI=3 type results if the present value cost were less than $16,618; none would if the cost were greater than $25,967. All DxHY TRI=3 type producers would choose to improve their farrowing management and facilities to the TRI+3 level if the present value cost were less than $17,464; none would if the cost were greater than $23818. All TRI-3 type producers would choose to improve their farrowing management and facilities to the TRI+3 level if the present value cost were less than $37,152; none if the present value cost were greater than $43,445.

Willingness to pay values are listed in Table 20 for all the analyses discussed in this section. The upper and lower bounds for the HxH producer are also reported and can be interpreted in the same manner as for the DxHY producer.

Feeding Efficiency

The original analysis contained a 10% waste factor on feeding efficiency of market animals. This waste factor was added to bring the experiment station results into greater conformity with actual commercial producer reports. The waste may be attributable to rodent damage and poor equipment which allows spillage of excessive quantities of feed. This waste factor could conceivably be reduced by either more stringent rodent control or better feed handling. To estimate the amount of feed used by an operation but not consumed by market animals this feed waste factor was reduced to 7.5%, 5% and 2.5%.

The resulting whole herd feed efficiency changes and change in key variables are reported in Table 21. The value of improving feed efficiency on NPV and Income appears to be linear, allowing a 'per change' discussion of the waste scenarios to be appropriate. The results indicate that for the 140 sow DxHY firm modelled a reduction of one tenth pound of feed per pound of gain results in a mean increase of $22,876 in NPV or $4,671 in Income. On a per sow basis, this is a $163.40 increase in NPV; $33.36 increase in Income. IRR increases from 16.8% for the 10% waste assumption to 19.7% for the 2.5 % waste assumption. Risk of the enterprise is reduced, seen by the CVs of NPV, Income and IRR being reduced as feed efficiency improves.

For the HXH producers a reduction of one tenth pound of feed per pound of gain results in a mean increase of $5,215 in NPV or $2,661 in Income. IRR

TABLE 20

UPPER AND LOWER BOUNDS ON THE WILLINGNESS TO PAY TO ADAPT THE SUPERIOR FARROWING MANAGEMENT FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Move From	Move To	Lower Bound	Upper Bound
		DxHY	
		------------------dollars	-----------------
TRI=3	TRI+3	17,464	23,818
TRI-3	TRI+3	37,152	43,445
TRI-3	TRI=3	16,618	28,967
		HxH	
		------------------dollars	-----------------
TRI=3	TRI+3	7,409	11,042
TRI-3	TRI+3	15,020	21,458
TRI-3	TRI=3	6,515	11,549

TABLE 21

THE IMPACT OF FEED MANAGEMENT ON ECONOMIC MEASURES FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Feed Waste (%)	10.0	7.5	5.0	2.5
DxHY				
Whole Herd Feed Efficiency				
Mean	3.71	3.65	3.59	3.54
Net Present Value				
Mean ($)	282,330	295,388	308,400	321,220
Standard Deviation ($)	20,143	19,759	19,308	19,163
Coefficient of Variation	7.13	6.69	6.26	5.97
Average Annual Taxable Income				
Mean ($)	100,528	103,178	105,828	108,468
Standard Deviation ($)	3,679	3,680	3,692	3,731
Coefficient of Variation	3.66	3.57	3.49	3.44
Internal Rate of Return				
Mean	.168	.178	.188	.197
Standard Deviation	.014	.014	.014	.014
HxH				
Whole Herd Feed Efficiency				
Mean	4.40	4.34	4.28	4.22
Net Present Value				
Mean ($)	60,426	64,478	66,678	69,814
Standard Deviation ($)	9,217	9,318	9,567	9,842
Coefficient of Variation	15.25	14.45	14.35	14.10
Average Annual Taxable Income				
Mean ($)	41,372	43,019	44,576	46,162
Standard Deviation ($)	2,789	2,847	2,827	2,851
Coefficient of Variation	6.74	6.62	6.34	6.18
Internal Rate of Return				
Mean	-.140	-.131	-.125	-.117
Standard Deviation	.038	.028	.028	.028

increases from -14.0% to -11.7%. Figure 18 illustrates the impact of improved feed efficiency on Income.

As in the number of litters per sow per year analysis, the less efficient breeding scheme does not benefit as much from an improvement in the whole herd feed efficiency as does the more efficient breeding schemes. Again, producers using poor breeding schemes should change breeding schemes rather than work on improving whole herd feed efficiency.

The willingness to pay analysis indicates that all DxHY producers with 10% feed wastage would choose to improve their feeding management and facilities to the 2.5% level if the present value cost were less than $8,312; none would if the cost were greater than $12,242. All 5.0% and 7.5% feed wastage producers would choose to improve their feeding management and facilities to the 2.5% level if the present value cost were less than $2,814 and $4,454, respectively; none if the present value cost were greater than $4,490 and $7,607, respectively. Table 22 contains upper and lower bounds for the HxH producers and is interpreted accordingly.

Financial Considerations

Analysis of the farm under various debt to asset ratios is performed to observe the effect of debt on NPV and variance. Using ratios of .3, .5 (original assumption) and .7, the results are shown in Table 23. Higher debt to asset ratios lead to higher return to assets as would be expected considering the leverage gained by the use of debt. The DxHY producer increases NPV approximately $1,100 for each 1% decrease in the debt to asset ratio. The same producer can expect to increase Income by approximately $230 for each 1% decrease in the debt to asset ratio. The HxH producer's change in NPV from using less debt is not as great as for the DxHY producer. The HxH

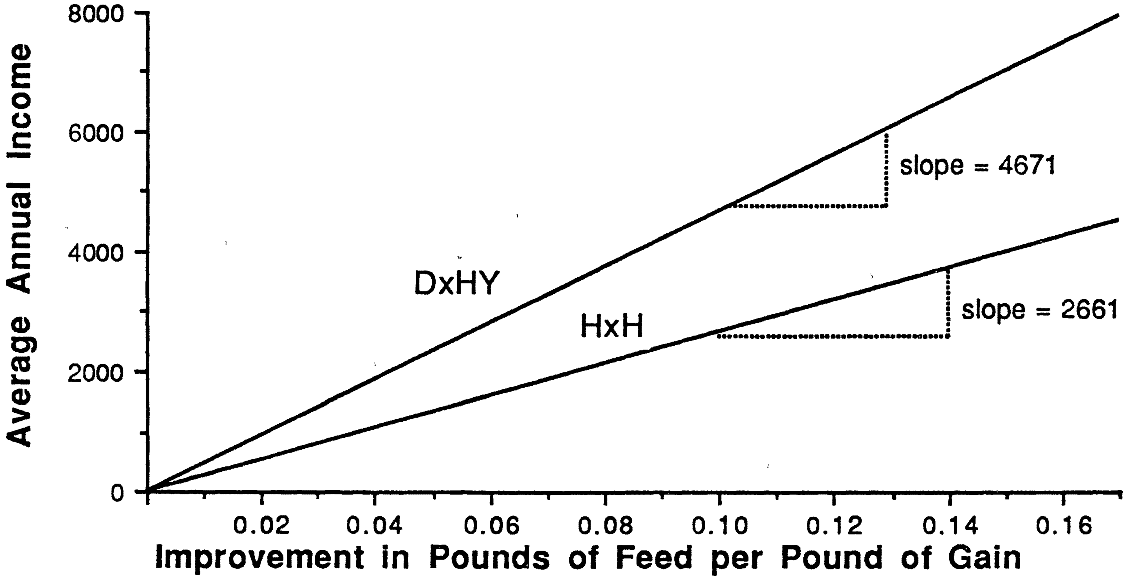


Figure 18. The Effect of Whole Herd Feed Efficiency Improvement on Income for a 140 Sow Farrow-to-Finish Confinement System

TABLE 22

UPPER AND LOWER BOUNDS ON THE WILLINGNESS TO PAY TO ATTAIN 2.5 FEED WASTAGE FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Move From	Lower Bound	Upper Bound
	DxHY	
	------------------dollars-----------------	
5.0% wastage	10,942	13,434
7.5% wastage	23,668	26,763
10.0% wastage	35,714	40,782
	HxH	
	------------------dollars-----------------	
5.0% wastage	$2,813	$4,490
7.5% wastage	$4,454	$7,607
10.0%wastage	$8,311	$12,242

TABLE 23

THE IMPACT OF DEBT ON ECONOMIC MEASURES FOR A 140 SOW FARROW-TO-FINISH CONFINEMENT SYSTEM

Debt to Asset Ratio	.30	.50	.70
	DxHY		
Net Present Value			
Mean ($)	304,263	282,330	259,610
Standard Deviation ($)	19,268	20,143	20,866
Coefficient of Variation	6.33	7.13	8.04
Average Annual Taxable Income			
Mean ($)	104,977	100,528	95,884
Standard Deviation ($)	3,646	3,679	3,709
Coefficient of Variation	3.47	3.66	3.87
Internal Rate of Return			
Mean	.127	.168	.235
Standard Deviation	.012	.014	.019
Coefficient of Variation	9.45	8.33	8.09
	HxH		
Net Present Value			
Mean ($)	74,551	60,426	50,441
Standard Deviation ($)	8,777	9,217	9,216
Coefficient of Variation	11.77	15.25	18.27
Average Annual Taxable Income			
Mean ($)	45,602	41,372	37,199
Standard Deviation ($)	2,704	2,789	2,819
Coefficient of Variation	5.93	6.74	7.58
Internal Rate of Return			
Mean	-.141	-.140	-.128
Standard Deviation	.023	.028	.035
Coefficient of Variation	16.31	22.14	27.34

enterprise experiences approximately $600 increase in NPV for each 1% decrease in the debt to asset ratio. On the other hand, the HxH producer experiences approximately an increase of $210 in Income for each 1% decrease in the debt to asset ratio. This deviates from the DxHY producer by only $20. Higher debt to asset ratios cause lower Income due to the interest expense deduction. Though a tax deduction is obtained from the interest expense, interest is still an expense which decreases income. The NPV of the producer with the least debt is greatest at the end of the ten year period. Using CV as a measure of risk, debt increases risk.

When the effect of debt on IRR is analyzed, a slightly different perspective is gained. When production is profitable, as for the DxHY producer, increased debt increases IRR and the standard deviation associated with that IRR. However, the standard deviation does not increase as quickly and the CV is reduced with debt. When production is unprofitable, as for the HxH producer, the same is not true. Debt appears to increase the IRR less quickly than the standard deviation associated with it. Hence, the CV of IRR for the unprofitable producer increases as debt increases. The increase in IRR for the unprofitable firm with higher debt does not conform to theoretical expectations.

Under the ratios assumed and the minimum asset to equity ratio necessary to remain solvent (.25), no farm was declared insolvent. The high debt to asset ratios may be expected to induce bankruptcy if the start-up period was modelled since this is the time when cash flow problems occur. The HxH scheme does indicate a negative internal rate of return but has sufficient financial resources to remain solvent for the ten year period modelled. When substantial improvements or replacement of facilities become necessary, such a producer might be forced to cease production. The simulations purposefully avoided facilities rejuvenation so that the genetic potential of the swine breeds would be the emphasis of the study.

Debt may be necessary for an individual to enter into production and/or expand. Producers should realize that from a risk perspective debt increases fluctuations in Income. Leverage works to magnify both upward and downward movements in income and, consequently, increases risk.

Source of Variation in NPV and Income

Risk is often measured by the standard deviation associated with an outcome variable. The higher the standard deviation, the greater the risk; and vice versa. The DxHY operation is simulated assuming the different stochastic production and marketing parameters are constant (i.e.. not stochastic) in an effort to analyze the major sources of risk. NPV and Income are the measures used in this section of the study and reported in Table 24.

As predicted in the model chapter, the mean NPV and Income for the various simulations are very similar to the mean NPV and Income for the base simulation where variances and covariances are allowed to interact in the model. Though the means are similar, they can not be called statistically insignificant and dismissed. The random numbers used to model the various scenarios in any outcome variable is real and due to the process modelled. It is not a statistical "luck of the draw" error.

Cleveland found that when correlations are not considered in stochastic models, the mean income can vary greatly from when correlation is considered. The different outcomes in the two research efforts could be due to greater price correlations in cattle production than in pork production or differences in model specification.

TABLE 24

CHANGES IN NPV AND INCOME VARIANCE WITH SELECTED VARIABLES HELD CONSTANT

Scenario	Net Present Value		Average Annual Taxable Income	
	Percent of Base		Percent of Base	
	Mean	Standard Deviation	Mean	Standard Deviation
No Production Variance	100.4	72.8	100.2	64.0
No Feed Efficiency Variance	100.0	98.2	100.0	97.0
No Litter Size Variance	100.2	76.2	100.2	67.6
No Price Variance	100.5	76.2	100.1	74.9
No Hog Price Variance	99.9	81.8	100.0	77.6
No Sorghum Price Variance	100.1	100.3	100.0	101.1
No Hog Concentrate Price Variance	100.1	100.4	100.0	100.2
No Feed Price Variance	100.2	101.0	100.1	100.9
Ten Year Average Prices with Price Variance	116.6	83.9	104.1	96.7
Ten Year Average Prices without Price Variance	116.6	63.3	104.1	73.4
No Livestock-Feed Correlation	100.0	100.7	100.0	101.2
No Correlation	100.1	98.4	100.0	100.2
No Random Variables	101.6	0.0	100.4	0.0

Eliminating the variation due to the stochastic production parameters causes total volatility to be 72.8% of the total variation in NPV and 64.0% of the total variation in Income compared to the base situation. When feed efficiency variance alone is assumed zero, the reduction in volatility is 1.8% and 3.0% for NPV and Income, respectively. Holding only litter size constant, on the other hand, reduces volatility 23.8% and 32.4% for NPV and Income, respectively. The volatility due to litter size greatly outweighs volatility due to feed efficiency. This adds to the importance of reproductive efficiency on income already discussed in the section discussing the ranking of breeding schemes.

Performing the same type of analysis on price volatility gives an indication of the impact of various prices on NPV and income volatility. When all prices (hog and feed) are held constant and only production variables are allowed to be stochastic, the NPV and annual income volatility is 76.2% and 74.9% of the base. Holding all hog prices constant at their mean for each year simulated reduced NPV volatility to 81.8% of the base; annual income volatility to 77.6%. Holding 1) only sorghum constant and 2) only hog concentrate constant and 3) all feed constant cause little change in the volatility of either NPV or annual income. The results indicate that hog prices are responsible for the majority of NPV and annual income volatility attributable to price variance.

The assumption inherent in the above discussion is that all volatility in NPV and average annual cash income is due to the random nature of the distributions of the variables. In other words, it assumes that annual price averages will not be equal from year to year. The question remains: if expected price changes could be eliminated and the average price expected each year identical, what would be the effect of the random components on NPV and income volatility? Simulating the model with 10 year average annual prices for each year of the simulation and allowing the unexplained component of the price fluctuation to remain in the model causes NPV volatility to drop to 83.9% and the Income volatility to 96.7%.

If average annual prices are used and all price volatility is eliminated, NPV and average annual cash income would still be volatile. The average annual taxable income would decrease in volatility by only 26.6%. If pork production became a completely regulated enterprise with the government guaranteeing a certain price without any fluctuations over a long period of time, producers could still expect income to vary by 73.4% of the prior system's volatility. Income varies considerably due to the variability of production factors.

The amount of volatility attributable to production processes is unexpected. The variance of livestock and feed prices is widely reported and easily recognizable. Producers, on the other hand, rarely keep production records and more rarely report them. When producer attainments are reported they are frequently aggregated so that an individual's results are not known from year to year. This model indicates that production related income volatility is greater than price related income volatility for farrow-to-finish pork production.

The decision to detrend market prices using the index of prices received by farmers is a critical resolution of this analysis. It is believed that since mean prices change each year, the model has a measure of volatility inherent apart from introducing a variance. To have used nominal data to derive a covariance matrix would have overstated the volatility due to prices. It is recognized that the variance of prices is smaller than intuitively reasonable.

The magnitude of the increase in the mean NPV and Income when a ten year mean price is assumed is greater than in any other simulation. Mean NPV increases 16.6% while mean Income increases 4.1%. The larger increase in mean NPV may be due to the timing of low prices in the base simulation. The low livestock prices of the base simulation tend to occur at the beginning of the ten year period. When the ten year mean prices are used, the early livestock prices rise causing a greater NPV due to discounting larger incomes earlier.

The covariance matrix used in the base simulations model a correlation between the two feedstuffs used, the four types of hogs sold and between the feedstuffs and hogs. The correlation between all but the hog types is statistically weak. To determine the impact of modelling this correlation, the correlation between livestock and feed was omitted. The NPV volatility increased slightly while the annual income volatility decreased slightly. If the near perfect hog and feed price correlation is not accounted for in the simulation, the NPV volatility decreases slightly while Income volatility increases slightly.

Management Considerations

The value of futures and options markets to help control price variability has been widely reported. Methods devised to increase income to pork producers have also been developed and reported. However, little work has been done to quantify the volatility of income due to production processes or to diminish production variance.

Though no definitive conclusions can be made in reducing production related variance, some observations from the management studies are listed below.

1) The most productive breeding schemes have the greatest variance in NPV and Income but the lowest coefficients of variation. Using the most productive breeding schemes decreases risk per dollar of income.

2) Increasing the number of litters per farrowing sow per year decreases the coefficient of variation of NPV and Income.

3) Improved farrowing supervision and facilities should help reduce the number of small litters. This has great potential in reducing production related risk since litter size variation contributes substantially to income variance.

4) Reducing feed waste both increases expected income and decreases the variance of income.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary of Problem and Procedures

Commercial pork production can be accomplished under a variety of management strategies. The size of operation, types of facilities, the breeding scheme utilized and the intensity of the breeding and feeding management are a few of the production characteristics which vary among producers. Regardless of the production choices made, income is volatile. The volatility of income, coupled with other factors, causes managerial difficulties and economic hardships for producers. While some producers appear to routinely fare better than others, the environment in which production occurs gives confusing signals to observers of the system.

The volatility of production and marketing factors and the dynamic nature of production stretch the tenets of neoclassical economic theory. It is difficult to equate marginal revenue with marginal cost when neither is known with certainty at the time of decision making. Utility maximization, expressed in stochastic dominance analysis, provides a framework to analyze production decisions under uncertainty.

The main hypothesis which this study addresses is: some breeding schemes and management strategies are more risk-efficient than others currently available to commercial producers. The specific objectives are: 1) to determine superior production practices under uncertainty and estimate the cost of nonuse to producers and 2) to quantify the amount of volatility attributable to selected variables in the production process.

Simulation of a 140 sow farrow-to-finish confinement operation over a ten year historical period is used to address the stated objectives. FLIPSIM V is modified to handle stochastic livestock production parameters. Stochastic simulation of the number of pigs weaned, feed efficiency, and livestock and feed prices helps to model the uncertainty observed by commercial pork producers. Animal science research data on Duroc, Hampshire and Yorkshire breeds of swine are used to imitate various breeding schemes.

The results of the stochastic simulation are evaluated using stochastic dominance theory to determine the most risk-efficient breeding scheme. Further analysis is performed to determine the impact of management on income and its volatility. The management strategies studied are the impact of: 1) number of litters per sow per year, 2) number of pigs weaned per litter, 3) feed waste reduction and 4) debt. The "willingness to pay" concept is used to determine the value of moving from one production technology or management level to another for producers with different risk attitudes.

The volatility of income attributable to the different stochastic variables is also estimated. The impact of eliminating the production related volatility is compared with the impact of eliminating the market related volatility. Production related volatility is restricted to that caused by number of pigs weaned and feed efficiency. Market related volatility accounts for both feed and livestock price volatility about an expected price and for feed and livestock price volatility about a 10 year average price.

Summary of Results and Conclusions

Due to heterosis, three breed terminal crosses are expected to fare best, followed by two breed terminal backcrosses, two breed terminal crosses and purebreds. Generally the results confirm these hypotheses but occasionally deviate from them. Those breeding schemes containing Yorkshires in the maternal position tend to rank higher than expected from a maximization of heterosis ranking.

The DxHY breeding scheme netted the greatest return for pork producers. The dominance of a three breed terminal cross over other breeding schemes conforms to expectations. Heterosis is greatest with this scheme. The presence of the Yorkshire breed in the maternal position also conforms to what swine breeders would expect. Yorkshires are known for their relatively large litter size and mothering ability. The analysis indicated which three breed terminal cross is economically superior and the approximate dollar amount by which it surpasses other breeding schemes.

Simulation, rather than producer data, is used because producer management styles have a large impact on income. For the 140 sow farrow-to-finish DxHY producer, the intensity with which a producer is able to manage the breeding facilities affect the producer's average annual taxable income by $7,018 per .1 litter per sow per year. Managers who can reduce the incidence of small number of pigs weaned per litter by insuring that litter size does not fall below the mean minus one standard error can expect their income to increase by $32.63 per sow per year. Conversely, those who are unable to save the large litters so that litter size never exceeds the mean plus one standard error can expect their income to be $28.24 per sow per year less than the average. The loss of income due to decreased feed efficiency is estimated at $33.36 per

.1 pound of feed per pound of gain on a per sow basis. Higher levels of debt decrease income by approximately $230 per 1% increase in the debt to asset ratio.

The interplay between management and genetic potential may obscure the economically dominant breeding scheme for commercial pork production. A producer with genetically inferior stock when compared to other producers might fare better economically if his management skills are sufficiently superior. Nevertheless, should the better producer with the inferior stock utilize the superior breeding scheme profits could increase. The choice of whether to work on increasing production through better management and facilities or through changing breeding schemes depends on which breeding scheme a producer is currently utilizing. Those utilizing inefficient breeding schemes would do better to change schemes than to fine tune their management and facilities. The use of simulation where all management and environmental factors can be held constant across breeding schemes is a powerful tool for analyzing alternatives.

In addition to income, the volatility of income is important to producers. Volatility of income arises from a variety of sources. The volatility associated with livestock prices and input costs, particularly feed, have been studied by several researchers. Several methods such as contracting and the use of futures markets exist to help reduce this volatility. Much volatility also comes from the uncertain nature of production. Production generated volatility may not be as obvious in pork production as in yields of cash crops which have strong, visible correlations with weather.

If there were no variation in livestock and feed prices over the ten year period, the standard deviation of NPV would decrease to 63.3% of the standard deviation of NPV when prices are volatile. Most of the NPV volatility due to prices comes from the volatility of livestock prices rather than feed prices. Eliminating livestock price variance reduces NPV volatility by 18.2% while eliminating feed price variance causes a 1% increase in NPV volatility. If all production variation were eliminated over the same ten year period, the standard deviation of NPV would be 72.8% of that when production is assumed volatile. Most of this volatility is due to the number of the pigs weaned per sow per year. Eliminating litter size variance reduces NPV volatility by 23.8% while eliminating feed conversion variance causes a 1.8% decrease in NPV volatility. Policy programs cannot adequately address production fluctuations. Various management decisions such as culling of inferior stock may alleviate some of the low observations. Animal scientists and agricultural engineers working in conjunction may be able to develop breeds and / or facilities which reduce production variance.

In conclusion, producers operate in an uncertain environment which obscures economically superior breeding schemes and complicates management decisions. Of the 27 breeding schemes modelled, the DxHY breeding scheme is the economically superior scheme. However, careful management of the breeding and feeding herds is required to maximize return, regardless of the breeding scheme used. Producers who use superior breeding schemes and who excel in management skills will fare best.

Limitations

The scope of this research is predominantly production oriented. Therefore marketing factors are included but not emphasized.

Litter size and feed efficiency are used as the representative measures of breeds. Several other traits such as litter weight, age to market, average daily gain and carcass quality have necessarily been omitted. The breeding scheme recommendations of this research are heavily dependent on the representativeness of the animal science data for various breeds and breeding schemes. Admittedly, there is much variability of genetic makeup even within a breed. Researchers at other universities have obtained other observations. The data used have been reported in the Journal of Animal Science and reviewed by peers. If the data do represent the breeds, as animal scientists have reported them, the recommendations are robust.

The data used in this analysis are obtained from experiments conducted in Oklahoma. Prices used are those which prevailed in Oklahoma during the period modelled. Litter size and feed efficiency data are from research completed at Oklahoma State University. These production standards may well represent others in the US and have been published in national journals but are acknowledged as being Oklahoma specific.

Assumptions which facilitated the study of genetic potential are: 1) existing production is assumed, 2) no start up difficulties are modelled, 3) the cost of changing from one management strategy to another is not addressed and 4) the size of the simulated enterprise is 140 sows. A moderately large operation is necessary to manage three breed terminal crosses where all female replacement breeding stock is raised. A confinement system with dirt lot gestation is assumed. Production standards, especially feed conversion, may change for slaughter hogs fed in dirt lots.

The volatility analysis is performed using animal science data to estimate the variance of production standards. These would best be compared to individual production variance to determine their appropriateness.

Proposed Extensions For Research

One of the most obvious extensions for research is the inclusion of more breeds and breeding schemes. This research utilizes Yorkshire, Duroc and Hampshire breeds and terminal crosses. Though these three breeds are in approximately 90% of the commercial hogs marketed (Luce), other breeds have their own particular genetic merit. Including such breeds as Landrace, Chester White and Spots would broaden the coverage of this research.

Though terminal crosses are genetically superior to rotational crosses, they bring additional problems to commercial pork production. The first drawback to using terminal crosses is the source of replacement breeding stock. This research assumes all replacement gilts are raised on the farm. This necessitates the maintenance of side herds to provide these replacements. Replacement gilts could be purchased but this increases the risk of importing disease into the herd and might increase breeding costs. Rotational schemes do not possess these problems and thus warrant further study.

Also rotational cross evaluation would allow an analysis of breeding schemes for small producers unable to maintain side herds and unwilling to purchase replacement gilts. An additional benefit of evaluating rotational crosses is quantifying the impact of rotational breeding on income volatility.

This research ends with estimates of the amount producers might be willing to pay to move to the dominant strategies. It gives no guidance regarding how the transition should occur or estimate of the cost of changing. A dynamic optimization study where the cost of changing and the most efficient path of change would greatly benefit producers already using an inefficient breeding scheme or management strategy.

Other assumptions in this research which might be elaborated on in future research are: 1) accounting for the carcass quality of various breeds if the animals are marketed yield and grade; 2) considering the effect of conception rate volatility on optimal facilities.

FLIPSIM has been modified so that it can address several timely issues as the data become available. An economic evaluation of the Chinese breeds of hogs when crossed with European breeds in commercial production can be performed as data become available. The price pharmaceutical companies can charge producers for chemicals (i.e. vaccines and porcine growth hormone) can be estimated if their effect on production can be quantified.

A SELECTED BIBLIOGRAPHY

Ahlschwede, William T., Charles J. Christians, Rodger K. Johnson and O. W. Robison. Crossbreeding Systems for Commercial Pork Production." Pork Industry Handbook Fact Sheet 39. Stillwater: Oklahoma State University Cooperative Extension Service. April 1988.

Anderson, Jock R., John L. Dillon and J. Brian Hardaker. Agricultural Decision Analysis. Ames: Iowa State University Press, 1977.

Bailey, D. V., B. W. Brorsen and J. W. Richardson. "Dynamic Stochastic Simulation of Daily Cash and Futures Cotton Prices." Southern J. Agr. Econ. 16 (1984):109-116.

Bailey, Elizabeth and Richard N. Boisvert. "A Risk Evaluation of Groundnut Genotypes in Drought Prone Areas of India." Cornell University Dept. of Agr. Econ. A.E. Res. 89-11, July 1989.

Barry, Peter J., John A. Hopkin and C. B. Baker. Financial Management in Agriculture. Danville, IL: The Interstate Printers and Publishers, Inc., 1979.

Beattie, Bruce, R. and C. Robert Taylor. The Economics of Production. New York: John Wiley and Sons, Inc., 1985.

Bennett, Gary L. "Alternative Swine Industry Breeding Systems." Paper presented at The Third World Congress on Genetics Applied to Livestock Production: Crossbreeding Programs for Swine, Poultry and Fish, G. E. Dickerson and R. K. Johnson (Eds.), Lincoln, NE, July 1986.

Bohnstedt, George W. and Arthur S. Goldberger. "On the Exact Covariance of Products of Random Variables." Amer. J. Agr. Econ. 64(1969):1439-1442.

Brigham, Eugene F. and Louis C. Gapenski. Financial Management: Theory and Practice. Fifth Ed. Chicago: The Dryden Press, 1988.

Caulfield, Jon P. "A Stochastic Efficiency Approach for Determining the Economic Rotation of a Forest Stand." Forest Science 34(1988):441-457.

Chiang, Alpha C. Fundamental Methods of Mathematical Economics. New York: McGraw-Hill Co., 1984.

Clements, Alvin M., Harry P. Mapp and Vernon R. Eidman. "A Procedure for Correlating Events in Farm Firm Simulation Models." Oklahoma State Univ. Exp. Sta. Bull. No. T-131, Stillwater, OK, 1971.

Cleveland, Sheila D. "A Simulation Model for Examining Profit Volatility in the Cattle Feeding Industry." M.S. thesis, Oklahoma State University, 1988.

Cochran, Mark J. and Rob Raskin. "A User's Guide to Generalized Stochastic Dominance Program for IBM PC Version GSD 2.1." Univ. of Arkansas, Dept. of Agr. Econ. and Rural Soc. Staff Paper SP 0688, 1988.

Conner, J. R., R. A. Dietrich, J. W. Richardson, C. J. Nixon and E. E. Davis. "Impacts of Federal Tax Laws and Economic Developments on the Texas Cattle Industry." Texas Agr. Exp. Sta. Bull. No. B-1590, 1987.

Dillon, John L. The Analysis of Response in Crop and Livestock Production. Second Ed. New York: Pergamon Press, 1977.

Dillon, J. L. and D. L. Scandizzo. "Risk Attitudes of Subsistence Farms in Northeast Brazil: A Sampling Approach." Amer. J. Agr. Econ.60(1978):425-35.

Doll, John P. and Frank Orazem. Production Economics: Theory with Applications. Columbus, OH: Grid, Inc., 1984.

Edwards, William M., Grytsje T. van der Sluis and Emmett J. Stevermyer. "Determinants of Profitability in Farrow-to-Finish Swine Production." North Central J. Agr. Econ. 11(1989):17-25.

Friedman, Milton. "The Methodology of Positive Economics." pp.3-43 in Essays in Positive Economics. Chicago: Univ. of Chicago Press, 1953.

Futrell, Gene. "Estimated Returns from Farrowing andFinishing Hogs in Iowa." Iowa State University Cooperative Extension Service. Ames, Iowa. 1974 - 1988.

Goodman, Leo A. "On the Exact Variance of Products." Amer. Stat. Assoc. Jour. 55(1960):708-713.

Grant, Dwight. "Optimal Futures Positions for Corn andSoybean Growers Facing Price and Yield Risk." USDA ERS Tech. Bull. No. 1751. March 1989.

Guiterrez, Paul. "The Impact of Selected Management Practices on the Economic Survivability of a Ranch Unit: An Analysis for a Southern Plains Ranch." Ph.D. dissertation, Oklahoma State University, 1985.

Hazell, Peter B. R. and Roger Norton. Mathematical Programming for Economic Analysis in Agriculture. New York: MacMillan Publishing Co., 1986.

Johnson, R. K. and I. T. Omtvedt. "Evaluation of Purebreds and Two-Breed Crosses in Swine: Reproductive Performance." J. Anim. Sci. 37(1973):1279-1288.

Johnson, R. K. and I. T. Omtvedt and L. E. Walters. "Evaluation of Purebreds and Two-Breed Crosses in Swine: Feedlot Performance and Carcass Merit." J. Anim. Sci. 37(1973):18-26.

Johnson, R. K., I. T. Omtvedt and L. E. Walters. "Comparison of Productivity and Performance for Two-Breed and Three-Breed Crosses in Swine. J. Anim. Sci. 46(1978):69-82.

King, Robert P. and Lindon J. Robison. "An Interval Approach to Measuring Decision Maker Preferences." Amer. J. Agr. Econ. 63(1981):510-520.

________. "Risk Efficiency Models." Chapter 6 in Risk Management in Agriculture. Peter J. Barry (Ed.). Ames, Iowa State University Press. 1984.

Knuth, Donald E. The Art of Computer Programming, Volume 2: Seminumeric Algorithms. Second Ed. Reading, MA.: Addison-Wesley Publishing Co., 1981.

Kramer, Randall A. and Rulon D. Pope. "Participation in Frm Commodity Programs: A Stochastic Dominance Analysis." Amer. J. Agr. Econ. 64(1981):119-128.

Larson, Harold J. Introduction to Probability Theory and Statistical Inference. Third Ed. New York: John Wiley and Sons, 1969.

Law, A. M. and W. D. Kelton. Simulation Modeling and Analysis. New York: McGraw-Hill Book Co., 1982.

Luce, William. Personal Interview. Stillwater, Oklahoma. November 1989.

Massey, Raymond E., J. E. Williams, Raymond Hunhke and William Luce. "The Economics of a 140 Sow Farrow-to-Finish Confinement System." Oklahoma State Univ. Extension Bulletin No. B-677. 1989.

McLaren, D. G., D. S. Buchanon and J. E. Williams. "Economic Evaluation of Alternative Crossbreeding Systems Involving Four Breeds of Swine. II. System Efficiency." J. Anim. Sci. 65(1987):919-928.

McCarl, Bruce A. "Preference Among Risky Prospects Under Constant Risk Aversion." South. J. Agr. Econ. 20(1988):25-33, vol. 2.

Meyer, J. "Choice Among Distribution." J. of Econ. Theory 14(1977):326-36.

Mjelde, James W. and Mark J. Cochran. "Obtaining Lower and Upper Bounds on the Value of Seasonal Climate Forecasts as a Function of Risk Preferences." West. J. Agr. Econ. 13(1988):285-293.

Moscardi, E. and A. de Janvry. "Attitudes Toward Risk Among Peasants: An Econometric Approach." Amer. J. Agr. Econ. 59(1977):710-16.

Naylor, T. H. Computer Simulation Experiments with Models of Economic Systems. New York: John Wiley and Sons, Inc., 1987.

Olson, Kent, Erlin J. Weness, Dary E. Talley, Perry A Fales and Rann R. Loppnow. Annual Report of the Southwestern Minnesota Farm Business Management Association. Univ. of Minn. Dept. of Agr. and Applied Econ. Economic Reports for 1985, 1986, 1987 and 1988.

Plain, Ronald Lee. "Adaptive Planning Under Price Uncertainty in Swine Production." Ph. D. dissertation, Oklahoma State University, 1981.

Pratt, J. W. "Risk Aversion in the Small and in the Large." Econometrica 32(1964):122-36.

Richardson, James W. and Clair J. Nixon. "Description of FLIPSIM V: A General Firm Level Policy Simulation Model." Texas Agr. Exp. Sta. Bull. No. B-1528, July 1986.

Ripley, Brian D. Stochastic Simulation. New York: John Wiley and Sons, Inc., 1987.

Sonka, Steven T. and George F. Patrick. "Risk Management and Decision Making in Agricultural Firms." Chapter 8 in Risk Management in Agriculture. Peter J. Barry (Ed.). Ames: Iowa State University Press. 1984.

Steel, Robert G. D. and James H. Torrie. Principles and Procedures of Statistics: A Biometric Approach. Second Ed. New York: McGraw-Hill Book Co., 1980.

US Department of Agriculture. Agricultural Prices. Washington: Agricultural Statistics Board, 1959-1988.

________. Livestock Detailed Quotations. Oklahoma City: Livestock and Seed Division, 1959-1988.

Varian, Hal R. Microeconomic Analysis. Second Ed. New York: W. W. Norton and Co., 1984.

Webster's Ninth New Collegiate Dictionary. Springfield, MA.:Meriam-Webster's Inc., 1984.

Wilson, E. R. and R. K. Johnson. "Comparison of Three-Breed and Backcross Swine for Litter Productivity and Postweaning Performance." J. Anim. Sci. 52(1981):18-25.

Wilson E. R. and R. K. Johnson. "Comparison of Mating Systems with Duroc, Hampshire and Yorkshire Breeds of Swine for Efficiency of Swine Production." J. Anim. Sci. 52(1981):26-36.

Wilson, Paul N. and Vernon R. Eidman. "Dominant Enterprise Size in the Swine Production Industry." Amer. J. Agr. Econ. 67(1985):280-288.

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