SWINE BREEDING SYSTEMS: A STOCHASTIC EVALUATION WITH IMPLICATIONS FOR EMERGING TECHNOLOGY

Raymond E. Massey and Joseph E. Williams

Abstract

The after-tax net present value for 27 swine breeding systems composed of Duroc, Hampshire, and Yorkshire breeds were simulated and ordered using stochastic dominance analysis. The concept of the value of information was expanded to develop the concept of the willingness to pay to adopt a new technology. For producers not currently using the dominant system, estimates of the allowable present value cost of adoption are reported and used to explain diverse production practices.

Key words: stochastic, emerging technologies, swine

Purdue, Auburn, North Carolina State, Iowa State, and Oklahoma State Universities have conducted extensive research on the performance of various breeds and crossbreeding systems of swine. The results indicate that significant, measurable breed differences exist, and that certain breeding systems are more productive than others. Wilson and Johnson, performing an economic analysis on swine breeding systems, found Duroc males crossed with Hampshire-Yorkshire females (DxHY) to have the highest production efficiency. Their results were published in the *Journal of Animal Science* in 1981.

Although Duroc, Hampshire, and Yorkshire breeds of swine constitute the majority of hogs marketed in the United States, the specific crossbreeding system of DxHY has not been uniformly adopted. Several possible reasons exist for the lack of adoption. First, producers entering production may not be aware of the findings. They may be deciding on their breeding strategy by observing other producers and adopting one of those producers' breeding strategies. This method of evaluating the most efficient breeding system does not consider the impact of management on production performance but attributes all of the achievements to the breeding system.

Second, the DxHY breeding strategy utilizes a terminal rather than a rotational cross. Terminal crosses require either the maintenance of side breeding herds for the raising of replacement stock or the purchase of replacement stock from another producer. Maintaining side herds is burdensome to management while, alternatively, purchasing replacement gilts can be prohibitively expensive, and there is a possibility that disease may be introduced.

Third, the cost of changing from the current breeding system to the more efficient one may be greater than the benefit of adoption. A careful analysis of the net gain should be performed before switching breeding systems.

The objectives of this paper are: (1) to extend previous studies on the efficiency of breeding systems by accounting for uncertain production and marketing parameters and (2) to develop one explanation, with managerial considerations, as to why adoption of the dominant system is slow. The slow adoption rate of the dominant system is considered in conjunction with uncertainty and the risk attitudes of producers.

The theory regarding slow adoption gives insight into how producers can maximize utility while concurrently producing with a less than profit maximizing breeding system. This information, once presented, should be useful in helping producers think rationally through their decisions regarding the replacement of one technique or technology with another.

The first section of this paper briefly presents the theory of stochastic dominance analysis and develops an extension on the value of information in an uncertain environment. The model and procedures used to evaluate swine breeding strategies are reviewed. The results of the analysis are presented, including estimates on the maximum allowable present value cost of adopting the dominant breeding strategy. Components of the cost of adoption are briefly discussed.

THEORY

Stochastic dominance allows the placing of risky prospects into efficient and inefficient sets. The effi-

Raymond E. Massey is an Assistant Professor in the Department of Agricultural Economics at the University of Nebraska, and Joseph E. Williams is an Assistant Professor in the Department of Agricultural Economics at Oklahoma State University.

This paper also appears as Oklahoma Agricultural Experiment Station Journal Manuscript No. J-5793, Oklahoma State University, Stillwater, OK.

cient set contains those prospects which are preferred by all decision-makers whose risk attitudes conform to various restrictions associated with each stochastic dominance criterion. This study makes use of two criteria: first degree stochastic (FSD) and generalized stochastic dominance (GSD).

FSD distinguishes between the efficient and inefficient sets of risky prospects for all decision-makers who have positive marginal utility for some performance measure, x. This requires only that the marginal utility, $U'(x)$, be greater than zero. The decision rule for FSD is F dominates G over the range [a, b] if:

(1) $F(x) \leq G(x)$ for all $x \in [a, b]$

with at least one strict inequality, where F(x) and G(x) are the cumulative distribution functions associated with distributions F and G, respectively.

GSD (Meyer) allows for greater discrimination among prospects by specifying alternative constraints on the utility functions of the decision-makers being modeled. These constraints are specified by the use of the Arrow-Pratt risk aversion coefficient (Pratt), r(x):

(2) $$r(x) = \frac{-U''(x)}{U'(x)}$$

where $U''(x)$ is the second derivative with respect to x of the utility function.

The decision rule for GSD is F dominates G when

(3) $$\int_{-\infty}^{\infty} [G(x) - F(x)]\, U'(x)\, dx \geq 0$$

subject to the constraint

(4) $r_1(x) \leq r(x) \leq r_2(x)$ for all values of x.[1]

The effective upper and lower constraints on the risk preferences of decision makers are determined by $r_1(x)$ and $r_2(x)$. $r_1(x)$ represents a more risk-preferring position than $r_2(x)$. Hence, the constraint $r_1(x) \leq r(x) \leq r_2(x)$ allows for an indefinite yet bounded classification of the decision-maker. Specifying $r_1(x)$ and $r_2(x)$ as negative and positive infinity, respectively, causes the GSD efficient set to be identical to the FSD efficient set. By narrowing the range of $r_1(x)$ and $r_2(x)$, GSD allows for greater discrimination in ordering risky prospects.

By identifying the utility function from the admissible set which is least likely to result in F dominating G, yet retaining the inequality, it is shown that the expected utility of F is greater than that of G for all utility functions in the admissible set. Hence, F dominates G.

Mjelde and Cochran define a producer's willingness to pay for information as a premium, π, which equals the amount the decision-maker can be charged in each state of nature before the decision-maker is indifferent to buying the information. This occurs when the expected utility of using the information, once the premium is paid, equals the expected utility of actions taken in the absence of the information without the premium having been paid.

Lower and upper bounds on this premium are obtained with generalized stochastic dominance by appropriate interpretations of the efficient set. If F(x) is the cumulative distribution function generated using decisions made utilizing the information and G(x) is the cumulative distribution function generated using decisions made not utilizing the information, and if F dominates G, then for all admissible utility functions, the expected utility of F is greater than the expected utility of G. The lower bound on the value of information is the minimum value of π such that $F(x-\pi)$ no longer dominates G. Subtracting the premium from each element in the distribution F(x) is equivalent to a parallel shift in the distribution F(x). At the lower bound, the expected utility associated with G is greater than or equal to the expected utility associated with F, given the constraints specified for the admissible utility functions.

The upper bound on the value of information is the minimum premium which causes G to dominate $F(x-\pi)$. The upper and lower bounds specify the range of the value of information for all decision-makers whose risk preferences lie between $r_1(x)$ and $r_2(x)$. Within the lower and upper bounds neither F nor G can be determined to dominate the other for the admissible class of utility functions.

The above logic applies not only to a narrow view of the value of information but can also be extended to account for the cost of adopting a new technology or management practice. In this framework, referred to as *willingness to pay*, π represents all costs of adoption rather than a premium paid for information; F represents an alternate technology not currently being utilized by the decision-maker and dominant to the technology currently being utilized, G. $F(x-\pi)$ represents a parallel shift in the distribution F resulting from the cost of adopting the new technology.

Subject to the specified risk aversion constraints, the lower bound on the willingness to pay represents

[1] For a more complete explanation of stochastic dominance theory, the reader is referred to King and Robison. For a mathematical explanation see Meyer.

the maximum amount at least one producer would be willing to pay to adopt the dominant technology. If the cost of adoption were below this bound, all producers defined by the constraints would choose to adopt. In the same manner, the upper bound on the willingness to pay represents the present value cost at which all producers defined by the constraints would choose not to adopt the dominant technology. Between these two bounds, the decision of whether or not a producer would choose to adopt is indeterminate. Depending on their risk attitudes, some procedures would choose to adopt, others would not. Further narrowing of the risk aversion constraints would be necessary to determine whether, say, a risk averse producer would adopt when a risk neutral producer would not, given a specified cost of adoption.

MODEL AND PROCEDURES

FLIPSIM V, developed by Richardson and Nixon (1986), is modified and used to model farrow-to-finish swine enterprises. FLIPSIM V is a firm-level, recursive process simulation model which simulates annual production, marketing, financial, management and income tax aspects of a farm over a multiple-year planning horizon. FLIPSIM V has previously been used to evaluate alternative farm programs (Duffy et al.), marketing strategies (Bailey et al.) and income tax policies (Richardson and Nixon). It has also been used in the area of farm management (Richardson et al. 1982) and risk management on hog-crop farms (Patrick and Rao).

The unmodified livestock subroutine, developed principally for cattle, was completely deterministic in its modelling of the production processes. Important modifications include the ability to stochastically simulate litter size. Stochastic litter size necessitates a variable feeder-finisher herd size since the number of animals raised in any one year is uncertain. The model's feeding logic was modified to permit the use of animal science feed-conversion data to compute the tonnage of various feedstuffs necessary to raise 230-pound market hogs. Feed conversion was also modelled as a random variable. Thus, the number of pigs born and marketed and the whole herd feed efficiency were modelled as stochastic rather than as deterministic processes.

A hypothetical 140 sow farrow-to-finish swine enterprise was used to estimate costs and returns from each of the 27 breeding systems over the 10 year period of 1979 to 1988 (Massey). Consistent with the actual facilities used when the data for the breeding systems were collected, the facilities in the simulation model consisted of confinement gestation and feeding barns and of dirt lot gestation pens. The investments in facilities were 1987 estimates discounted to 1976. The system was assumed to have been in full operation at the beginning of the simulation. This assumption allows the modelling of continuous production without start-up peculiarities and inefficiencies affecting the analysis.

Production standards included: (1) 2.42 litters per farrowing sow per year; (2) 87 percent of females introduced to boars farrow; (3) Sows comprise 68.4 percent of the farrowing females while gilts comprise 31.6 percent; (4) 16.5 hours of labor per sow per year are required, with family members providing all the labor required and receiving no explicit wage for their labor (Massey et al.).

Breeding stock were assumed replaced after the fourth farrowing or when failure to conceive after first breeding occurred. The modelled firm followed a typical pork production practice of replacing breeding stock with gilts raised on the farm. For terminal crosses this required that the breeding herd be composed of multiplier herds which produce replacement gilts. For example, the HxDY breeding system uses a Hampshire (H) boar mated to a Duroc (D) - (Y) Yorkshire cross for the majority of its matings. To supply the Duroc-Yorkshire gilts, a multiplier herd of purebred Yorkshire females was maintained, and Yorkshire and Duroc boars were mated to these females.

There are two ways to set up the replacement stock herds in the two-breed terminal backcrosses and three-breed terminal crosses. Both breeding systems were used in this analysis (Table 1). The first letter in the notation represents the sire breed. The letter(s) after the "x" represents the breed(s) of dam. The last letter of the breed of dam notation represents the smallest purebred herd necessary to maintain the breeding system. The letter combination (order important) represents the intermediate size breeding herd necessary to maintain the breeding system. Within this herd, the first letter represents the breed of sire and the second letter represents the breed of dam.

The model was iterated 100 times with the resulting after tax net present values (NPV) used to derive cumulative distribution functions of the swine enterprise. NPV was computed using a discount rate of 10 percent. The cumulative distribution functions were used to evaluate the breeding systems using first degree stochastic dominance (FSD).

DATA

Edwards, van der Sluis and Stevermyer report the importance of feed efficiency and litter size in their study of the determinants of profitability of farrow-to-finish pork production. It was assumed in this

Table 1. Herd Composition of Various Breeding Systems

Multiplier and Base Breeding Herds	Breeding Herd	Boars	Offspring Disposition
	Percent Purebreds	(number)	
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	100	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	100	12	
	Two-Breed Terminal Crosses		
Purebred (eg. YxY)	19	2	Replacement Gilts
Two Breed Crosses (eg. DxY)	81	9	Slaughter
Total	100	11	

study that the two most critical production variables for pork producers are feed efficiency and litter size. These variables serve as proxies for the particular breeding systems. 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.

This research utilized swine performance 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, and Wilson and Johnson). All four experiments were conducted on various crosses of Yorkshire, Duroc, and Hampshire breeds of swine. All four measured number of pigs weaned per litter of the crossbreeds and the pounds of gain per pound of feed of their respective progeny.

These two traits were both reported to be significantly different for different breeds and breeding systems. The two traits are considered by animal geneticists to be mutually independent. Litter size is significantly smaller for gilts than for sows (Johnson et al. 1978). The actual values used as the enterprise litter size was a weighted average of gilt litter size and sow litter size. Table 2 presents a summary of the data used to represent the breeding systems. The standard error associated with litter size and feed conversion were the same across breeding systems. They are .4467 and .0048, respectively.

The prices used in this report represented Oklahoma prices for livestock and feed ingredients. Monthly Oklahoma City data were available from 1959 to 1988 for market hogs, sows and grain sorghum. Sorghum price data used were prices received by farmers in Oklahoma. To these, a 10 percent markup was added to reflect the margin of distributors and any other marketing costs (Richardson and Nixon). Oklahoma hog concentrate prices were reported in the USDA *Agricultural Prices*. The hog concentrate price data used were reported as prices paid by farmers. Non-breeder gilt and cull boar prices were set at 95 and 65 percent of market hog prices, respectively (Plain). All mean annual prices used in the simulation model (1979-1988) represented simple averages of either the monthly or quarterly prices reported.

The distribution associated with the prices was assumed normal and multivariate across all livestock and feed categories. Hence, one covariance matrix for all prices was computed using SAS. Prices were detrended to remove the impact of inflation before the covariance matrix was computed. This matrix was used to compute an upper triangular A matrix (Clements et al.) necessary to generate random, multivariate normal deviates on prices. The index of prices received by farmers in the US (1910-1914 =

Table 2. Descriptive Characteristics of 27 Hog Breeding Schemes Analyzed

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

Note: D = Duroc, Y = Yorkshire, H = Hampshire.

Table 3. Stochastic Output from the Simulation of 27 Swine Breeding Schemes

Breeding Scheme	Net Present Value	
	Mean	Standard Deviation
	(dollars)	(dollars)
	Purebreds	
DxD	65,869	28,884
HxH	60,426	29,146
YxY	200,361	58,650
	Two-Breed Terminal Crosses	
DxH	124,124	41,397
DxY	216,816	61,414
HxD	97,768	36,448
HxY	204,315	59,738
YxD	184,361	54,150
YxH	136,761	43,569
	Three-Breed Terminal Crosses	
DxYH	265,946	66,154
DxHY	282,328	63,697
HxYD	254,336	65,142
HxDY	261,372	66,151
YxHD	195,689	57,528
YxDH	202,905	58,492
	Two-Breed Terminal Backcrosses	
DxDH	216,127	61,367
DxHD	208,980	60,465
DxDY	193,885	57,379
DxYD	187,035	55,222
HxDH	140,721	43,506
HxHD	135,196	42,969
HxHY	173,516	53,100
HxYH	160,459	50,204
YxDY	217,350	61,408
YxYD	210,464	60,453
YxHY	208,269	60,412
YxYH	193,897	57,290

Note: D = Duroc; Y = Yorkshire; H = Hampshire.

100) as reported by the USDA was chosen to detrend the data.

The differing reproductive and feed efficiencies of the breeding systems cause the problem to become a multiproduct, multiple input production process. Though all systems produce only hogs, each class of hog is produced in different proportions depending on the system. Varying quantities of the two feedstuffs are utilized depending on the breeding system modelled. The variances and covariances of production parameters and prices interact to create a stochastically complex process.

RESULTS

The modified version of FLIPSIM V was used to simulate 27 breeding systems possible using various combinations of Hampshire, Yorkshire, and Duroc hogs. Table 3 reports the mean and standard deviation of the NPV for the 27 breeding systems.

Three-breed terminal crosses with the Yorkshire breed in the maternal position tend to outperform other breeding systems. The noticeably low net present values of the purebred hog producers are probably due to the model's specifying that they market their product as market hogs rather than as breeding stock. Typically, purebred hog producers raise purebreds for sale as breeding animals at a premium above slaughter hog price and therefore would realize a greater expected NPV than is demonstrated in this model.

The DxHY breeding system is stochastically dominant over other breeding systems using FSD. This result includes all decision-makers who prefer more wealth to less wealth regardless of their risk attitudes. The superiority of the DxHY breeding system supports the conclusions of Wilson and Johnson noted earlier. Confirmation of the superior breeding system using a different mode of analysis strengthens the argument for its dominance.

The question now remains: why isn't the DxHY system being adopted with greater speed by producers? The "willingness to pay" concept is used to address this question. The risk attitudes of producers and their subjective estimates of the probable costs of adopting a new breeding scheme are considered within the willingness to pay framework to explain sluggish adoption of the DxHY system.

The upper and lower bounds on the willingness to pay for the 26 breeding systems not in the FSD efficient set are listed in Table 4 under the risk attitude constraints of $-.000295 < r_a < +.000295$. This range of risk attitudes closely corresponds to the interval reported by Wilson and Eidman to encompass the majority of Minnesota pork producers.

The interpretation of the bounds listed in Table 4 is as follows. If a group of producers was currently producing with the DxHY system and believed the present value cost of adoption of the DxHY system to be less than $15,027, all of the producers whose risk preferences lie between -.000295 and .000295 would opt for the change. If the present value cost of adoption were greater than or equal to $15,027, at least one producer would choose to continue operating as is, with the DxYH breeding system. If the present value cost of adoption were greater than $18,903, all producers would choose to remain with the inferior production practice. Each breeding system can be analyzed in the same method described above.

The present value cost of adoption would include the costs of obtaining information, of liquidating old breeding stock and purchasing new breeding stock over time, and of the probable inefficiencies associated with a change in production technologies. Furthermore, an additional premium might be added to the cost of adoption to account for the possibility of introducing disease and receiving inferior breeding stock.

Because the variable used to determine the optimal breeding system is net present value, the values reported in Table 4 are dependent upon the producer's having a discount rate of 10 percent. Higher discount rates would increase both the lower and upper bounds; lower discount rates would decrease the bounds. Thus a producer expecting a higher than 10 percent return on investment may be less willing to adopt than would be suggested by the bounds,

Table 4. Upper and lower Bounds on the Willingness to Pay to Adopt the DxHY Hog Breeding Scheme for a 140 Sow Farrow-to-Finish Confinement System

Breeding Scheme	Lower Bound	Upper Bound
	- - - - - - - - dollars - - - - - - - -	
DxYH	15,027	18,903
HxDY	19,195	22,816
HxYD	25,880	29,156
YxDY	60,284	68,533
DxY	60,924	69,081
DxDH	61,430	69,696
YxYD	66,620	75,853
DxHD	73,551	83,599
YxHY	67,828	77,249
HxY	68,524	69,081
YxDH	73,551	83,600
YxY	75,690	86,100
YxHD	90,032	103,480
YxYH	80,308	90,971
DxDY	87,812	100,302
DxYD	81,796	92,780
YxD	81,703	92,751
HxHY	100,088	114,325
HxYH	130,419	152,636
HxDH	112,241	129,317
YxH	135,809	158,403
HxHD	134,432	156,443
DxH	146,718	170,443
HxD	169,463	203,581
DxD	199,593	243,996
HxH	204,947	250,136

even if that producer's risk preferences were correctly specified by the constraints.

The above information offers insights into answering the question of why all pigs are not produced with the same system. First, the dominant breeding system may not be readily known to producers. This model was able to determine the genetically superior breeding system by subjecting all systems to the same management and environmental influences. Genetic merit alone is measured.

By observing commercial production alone it is impossible to differentiate between genetic potential and managerial/environmental impacts. A producer using an inferior breeding system may perform as well or better than one using the dominant system. When management influences are attributed to genetic potential, the dominant system may be misspecified.

Second, should a producer using an inferior system become convinced of that fact, the present value cost of adopting the dominant system considered in conjunction with the producer's risk attitude can preclude the adoption of the dominant system. Indeed, two producers currently utilizing identical, inferior systems and contemplating adoption of the dominant system can logically arrive at two different responses.

In the previous example, an extremely risk preferring DxYH producer ($r_a = -.000295$) contemplating adoption of the DxHY system would choose not to adopt if the present value cost were \$15,027. A risk neutral DxYH producer ($r_a = 0.0$), on the other hand, would choose to adopt if the present value cost were \$15,027.

The net present cost of adoption for some of the superior systems may preclude adoption of the efficient set. However, the lower bound quickly increases to a point where adoption would appear efficient. For example the DxY cross is the most efficient two-breed terminal cross, yet the DxHY system would still be preferred if adoption costs were less than \$60,924. The question essentially becomes one of delineating the true cost of adoption. The components of the cost are briefly explained below.

(1) Cost of purchasing alternative breeding stock. The cost of purchasing alternative breeding stock depends on the breeding system currently being used. Some systems (i.e. DxYH) may require only the purchase of limited breeding stock to attain the DxHY system. Other systems (YxD) may require a near-complete purging of the current breeding herd and purchase of another. The process of replacing the herd, whether abruptly or over time, will affect the cost of purchasing alternate stock. Determinants of the price of purchasing replacement stock include breed price differentials and the timing of replacement. Liquidating an inefficient herd and purchasing replacements may be prohibitive if hog prices are high. But later, after hog prices have declined, adoption may become feasible.

(2) The possibility of introducing disease. Whenever new stock are purchased and brought into a production system, the possibility of introducing disease increases. Unfortunately, no empirical data exist to quantify the increased danger of disease. Nevertheless, the subjective estimate of the producer is probably the most appropriate measure (Anderson et al.). Surely it is the estimate which is important when the producer is making a decision. This subjective estimate has the potential to influence significantly the decision to adopt.

A nationwide survey of pork producers showed that 75 percent of the respondents raised their own replacement gilts. These respondents also listed herd health as the major factor in their selection of where to buy breeding stock (Miller). Veterinarians suggest that all animals to be brought on a farm be tested for pseudorabies, isolated for one month, and retested before being added to the herd (Fleming). A strong fear of introducing disease may cause a producer to summarily reject adoption or place so high a premium on purchasing "clean" stock that the purchase cost becomes prohibitive.

(3) Adoption process inefficiencies. Usually during periods of change, inefficiencies occur. For example, the new stock may not arrive on the scheduled date, which would lead to inefficient facilities utilization, or the rigors of travel may cause the purchased stock to perform at sub-par levels. Regardless of the problem, inefficiencies have the potential to disrupt normal production and (A) decrease revenue through decreased output or (B) increase average cost through less efficient use of both variable and fixed inputs.

(4) Cost of education and information. The dominant system has been made known free of charge to potential users through the research reports of animal scientists and agricultural economists. The methodology of utilizing a three-breed terminal cross may require educational expense. Locating animals to purchase also entails a cost associated with information.

(5) Depending on the system currently utilized, adoption may increase labor, transportation, medical, and other expenses of managing a farrow-to-finish enterprise.

(6) Cost of raising replacement stock. In the short run there should be a decreased cost associated with raising replacement stock. Females, which in the inferior system were being raised for replacement gilts, can now be sold as market hogs. The introduction of purchased females into the herd will mean a short-run increase in the number of females sold as market hogs. This should temporarily increase gross revenue to the producer considering adoption and should be included in the decision process.

CONCLUSIONS

Using a simulation model of a 140 sow farrow-to-finish confinement system, the genetic merit of Duroc, Hampshire, and Yorkshire purebred and crossbreed systems were evaluated. The evaluation was accomplished by accounting for production and marketing uncertainty and through use of stochastic efficiency criteria. Litter size and feed efficiency were used to represent the various breeding systems. Data were from experiments conducted by the Oklahoma State Experiment Station in El Reno, Oklahoma. The most efficient swine breeding system, as determined using first degree stochastic analysis, is Duroc males mated to Hampshire-Yorkshire females (DxHY).

The reason the DxHY system is not more quickly adopted may be due to the cost of adoption as viewed from the risk attitude perspective of the producer. Perhaps central to the argument is the cost of purchasing new stock and the subjective probability of introducing disease that each producer associates with adoption.

The analysis yields a decision-making framework not only for the adoption of alternative swine breeding systems but for other technologies as well. When the adoption of new technologies into an existing system is being considered, both the cost of the technology and its potential impact on the operation of the firm must be considered. Further research is needed on the peculiarities of the production process during the initial adoption phase and its impact on decision-making.

REFERENCES

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." *So. J. Agr. Econ.*, 16(1984):199-222.

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.

Duffy, P.A., J.W. Richardson, and E.G. Smith. "The Effects of Alternative Farm Programs and Levels of Price Variability on Different Size Farms." Paper presented at the annual meeting of the AAEA, Ithaca, NY, 1984.

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

Fleming, Bill. "PRV: Why Wait?" *National Hog Farmer.* June 15, 1990. pp. 26-29.

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., 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.

Johnson, R.K., 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.

King, Robert P., and Lindon J. Robison. "Risk Efficiency Models." *Risk Management in Agriculture,* Chapter 6. Peter J. Barry, Ames: Iowa State University Press, 1984.

Massey, Raymond E., "A Stochastic Evaluation of Swine Breeding Schemes and Management Strategies." Ph.D. dissertation, Oklahoma State University, Stillwater, OK, 1990.

Massey, Raymond E., Joseph E. Williams, Raymon L. Huhnke, and William D. Lace. "An Economic Analysis of a 140 Sow Farrow-to Finish Swine Operation in Oklahoma." Oklahoma State Univ. Exp. Sta. Bull. B-788, Stillwater, OK, Jan., 1990.

Meyer, J. "Choice Among Distribution." *J. Econ. Theory,* 14(1977):326-336.

Miller, Dale. "Seedstock Sales Profile." *National Hog Farmer.* Sept. 15, 1989, pp. 52-58.

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.

Patrick, George F., and Ananth S. Rao. "Crop Insurance's Role in Risk Management on Hog-Crop Farms." *North Cent. J. Agr. Econ.,* 11(1989):1-10.

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):122-136.

Richardson, J.W., C.M. Lemieux, and C.J. Nixon. "Entry into Farming: The Effects of Leasing and Leverage and Firm Survival." *So. J. Agr. Econ.,* 15(1983):139-145.

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

Richardson, J.W., and C.J. Nixon. "The Economic Recovery Act of 1981: Impacts on Farmers' Liquidity, Equity, and Growth." *J. Farm Managers and Rural Appraisers,* 46(1982):10-15.

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

US Department of Agriculture. *Livestock Detailed Quotations.* Oklahoma City: Livestock and Seed Division, 1959-1988.

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