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Energy Restriction During Development in Breeding Gilts: An Economic Analysis

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ENERGY RESTRICTION DURING DEVELOPMENT IN BREEDING GILTS: AN ECONOMIC ANALYSIS

by

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Swine production has become a low-margin business. As costs of production have increased, producers are continuing to increase efficiency in market pig production and gilt development. Restricting energy intake during gilt development could have a positive impact on a producer's bottom line, but few studies have economically analyzed production differences caused by energy restriction.

This study utilized gilt development and market pig production data from biological studies that included a 2x2 factorial arrangement of half-sibling maternal lines (LWxLR and L45X) entering two gilt development programs. In one program, gilts were fed on an ad libitum basis. In the other, gilts were restricted to 75% of ad libitum energy intake from approximately 123 days of age until breeding (approximately 226 days of age).

The gilt development data were analyzed in an enterprise budget in both a deterministic analysis where 2004 through 2006 average prices were used and in a stochastic experiment where a simulation engine was used to generate price data with the same correlations and means as historical prices.

In both genetic lines, energy-restricted gilts had a greater probability of reproductive success than ad libitum gilts. Results from the budget showed both LWxLR

and L45X energy-restricted progeny generated greater profits than ad libitum offspring. Restricted LWxLR market pigs had a lower breakeven selling price than ad libitum LWxLR progeny ($38.12/cwt restricted vs. $38.60/cwt ad libitum) while ad libitum L45X progeny had a lower breakeven selling price than restricted L45X offspring ($38.07/cwt ad libitum vs. $38.21/cwt restricted).

In the stochastic simulation, both LWxLR and L45X restricted progeny generated greater profits than their ad libitum counterparts in 93.7% and 79.2% of the iterations, respectively. Restricted LWxLR market pigs had lower breakeven selling prices than ad libitum LWxLR market pigs at all iterations while ad libitum L45X progeny had lower breakeven selling prices than restricted L45X progeny in 89.7% of the iterations of the simulation experiment.

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Chapter 1: INTRODUCTION

1.1 Motivation

Swine production is centered on the constant pursuit of increasing efficiency in breeding programs and market swine production. Feed costs have increased in recent years due to an increased demand for corn bio-energy production and index fund speculative buying in the corn futures markets. Cost of gain for market swine has increased and maintaining a breeding herd is more expensive given increased input costs. Thus, swine producers have faced a shrinking profit margin and have an increasing need for further production efficiencies. Reducing the feed cost of breeding gilt production could improve swine producers' profitability. Additionally, sows that have a greater probability of producing more piglets would be advantageous to producers if the increased production led to a profit increasing outcome. Historically, the number of pigs per litter and annual litters per sow have trended upward sharply (USDA National Agricultural Statistics Service Hogs and Pigs Report) thus reducing the size of the U.S. breeding herd. However, sow replacement rates have been increasing for the past 10-20 years (Johnson and Miller, 2005).

The traditional method of developing breeding gilts is to feed these females on an ad libitum basis until they reach a body weight of 300 lb., at which point they are bred. The conventional reasoning behind self-regulation of feed intake is to grow the animals as fast as possible to hasten the onset of puberty as more mature animals have a greater likelihood of successful conception. However, body weight has not been conclusively found to affect age of puberty (Newton and Mahan, 1992). Additionally, this process results in an increased probability of overweight animals and, from an intuitive viewpoint, the possibility for lost reproductive production as heavier animals would not be optimal breeding stock. Increased body weights could also cause mobility problems later in life, leading to increased culling rates or even death losses, both of which producers intend to minimize.

One way to eliminate the problems brought about by self-regulation of feed intake and lower the feed cost of producing breeding gilts is to restrict feed intake for a period of time before puberty. Developing gilts in this manner is not completely revolutionary; however, little economic analysis has been done to evaluate whether it is economically optimal. Because the final determinant of whether innovation occurs is how it affects profitability, purely analyzing differences in reproductive production between gilts from different development programs is inadequate for fully comprehending how such a change could potentially affect swine producers. Rather, all parameters need to be accounted for when analyzing how such a change would affect swine production. For instance, if increased production is achieved by a greater increase in production costs (the marginal value product [MVP] is less than the marginal factor cost [MFC]), this outcome would not be economically advantageous because the level of production in this scenario is economically suboptimal. Because prices are not static, determining the optimal production program for gilts would change at differing input and output price ratios. At low input/output price ratios, one would assume the increased production would be economically beneficial because the marginal product would be produced for less than the cost of production ($MVP > MFC$, resulting in an increase in total profit [π]). Conversely, at high input/output price ratios, one would assume the increased production would be suboptimal because the cost of production would be greater than the marginal product ($MVP < MFC$, resulting in a decrease in π). Therefore, because price ratios have a large effect on the optimal gilt development system and also because there are both positive and negative effects of energy restriction during gilt development, a comprehensive budget would need to analyze how input and output prices affect profit, not just how production levels are affected by gilt development systems.

Given the recent increase in volatility of commodity markets, a budget analysis would need to account for profit variability caused by market fluctuations. For instance, if the total profit of the restricted-fed gilts is greater than that of the ad libitum gilts, but the variability of the restricted-fed system is also greater, restricting feed intake might be a sub-optimal outcome. A producer's personal level of risk tolerance would also affect which solution would be optimal in this case. A risk-averse producer might forgo the greater potential profit if it is accompanied by increased variability of returns while a more risk-tolerant producer might decide that increasing profit variability is a good trade-off for an increase in profit. Regardless, a budget analysis that analyzes the differences between gilt development systems would need to quantify the variability of returns caused by the volatility in commodity markets.

This research analyzes the economics of production differences between differing gilt development programs while taking into account commodity market volatility. Additionally, this study will establish decision rules swine producers can use to compare potential returns between development systems.

1.2 Objectives

Much research evaluating energy restriction during development in livestock production has been published e.g., (Klindt, Yen, and Christenson, 1999; Roberts et al., 2007; Funston and Deutscher, 2004; Stalder et al., 2000; Sorensen, Danielsen, and Busk, 1998). However, no research yet exists that analyzes economic differences between gilts from conventional and energy-restricted development systems. Research is especially lacking that evaluates these economic differences, given the increase in volatility seen in recent commodity markets. This is important because the optimal gilt development program may change at different input and output price levels. This project will calculate the profit differences between development systems in order to allow producers to make more confident decisions even in uncertain agricultural markets.

This study will evaluate production data from Johnson et al. (2007) in the context of enterprise budgets. The production data were obtained from approximately 650 gilts over the course of 4 replications. The objectives of this analysis are to:

1. estimate the returns to each development system
2. analyze and quantify the variability of the returns to each system through a simulated budget framework to determine the variability of each system.
3. establish decision rules to select the more profitable gilt development system under various market conditions

Three-year historical averages for commodity and energy prices will be used to economically evaluate development programs, analyze and quantify variability, and estimate how this profit variation will impact breeding production decisions. Additionally, decision tools that can be used in swine breeding operations will be included in this study to help producers make more informed production decisions about the gilt development system they use to develop breeding stock.

1.3 Organization

This thesis is composed of five chapters that analyze economic effects from differing gilt development systems. Chapter 1 conveyed the motivation behind this thesis as well as the objectives of the project. The second chapter will review the literature on energy restriction during gilt development and summarize results from earlier studies. Developing a budget analysis tool and a simulation experiment capable of comparing gilts from different genetic lines and treatment groups will be the focal point of Chapter 3. Chapter 4 will discuss the results from the budget and evaluate differences between gilt development programs. Additionally, this chapter will provide a stochastic simulation experiment to evaluate variability of returns across each treatment group at different input and output price levels. Chapter 5 will provide conclusions and implications of this study and discuss future research needs.

Chapter 2: LITERATURE REVIEW

Reducing feed costs during gilt development without negatively affecting reproductive performance could have a large impact on gilt development costs. However, most of the literature evaluating the effects of energy restriction during development in gilts gives results that are economically ambiguous due to conflicting productivity changes. This literature focuses on differences in reproductive productivity between control and experimental groups. Unfortunately, few studies exist that consider the impact of reproductive performance on economic returns. However, there are several studies that evaluate production data from different energy levels in gilt development systems. The following literature review will discuss the results of energy restriction during gilt development.

2.1 Effects of Feeding Level on Age of Puberty

One commonly held belief in the swine breeding production community is the need for gilts to reach a minimum weight prior to breeding. The reasons behind this logic are two-fold: (1) higher feed intake during the development stage will hasten sexual maturity, and (2) sows need to build a nutrient reserve to allow their bodies to better manage the stress of reproduction. However, the increased body weight also requires additional maintenance energy and therefore increases feed costs over the life of the sow. Thus, results from studies in which energy was restricted in breeding gilts need to be carefully analyzed.

Newton and Mahan (1992) found that restricting feed intake in gilts to 75% of ad libitum (A.L.) levels did not have an effect on the age of puberty, although gilts fed a ration equivalent to 50% of A.L. levels did enter puberty at a later age. In this study, three treatments were used to assess the effects of feed intake on age of puberty. From 4.5 to 9 months of age, gilts in the two experimental groups were either given 50% or 75% of feed intake consumed by the control group (which was given full access to feed). Body weight and backfat were found to be inversely proportional to feed intake, but the largest determinant of puberty in this study appeared to be age. However, as stated earlier, higher levels of feed restriction (50% of A.L.) also can increase the age when gilts reach puberty.

This study has important implications for evaluating energy restriction during gilt development. According to Newton and Mahan (1992), a producer could potentially restrict energy of gilts to 75% of ad libitum intake without seeing an increase in age of puberty. Therefore, the producer would be able to take advantage of lower feed costs without having the disadvantage of gilts developing at later ages which would then lead to a decrease in total costs.

Protein restriction during lactation and its subsequent effect on reproductive performance was the subject of a study by Clowes et al. (2003). These authors restricted protein intake during lactation and proved that when a sow is deprived of dietary protein, and thus forced to utilize a large percentage of her body protein (more than 9-12%), this has a negative effect on litter growth, ovarian function and, therefore, reproductive performance. These results argue for a minimum weight at breeding to allow dams an adequate reserve of protein during lactation. However, because lactation diets are generally fed on an ad libitum basis, it would be logical to assume as long as the lactation diet fed to nursing dams would have an adequate level of protein, protein deficiencies during lactation could be avoided, and the minimum weight at nursing could be reduced because the protein reserve would not be as vital to future reproductive performance.

2.2 The Effect of Energy Restriction on Reproductive Performance

While there is little research that analyzes the economic effects of energy restriction, there is a wealth of research on the effects of energy restriction on breeding animal production. For instance, in a study done by Roberts et al. (2007), first parity pregnancy rates tended to be reduced (P=0.11) for breeding heifers restricted to 80% of intake versus those given ad libitum access to feed, but the authors admitted their sample size was not large enough to draw strong statistical inferences. Additionally, the authors hypothesized that a difference in pregnancy rate would be important to producers. The 5% reduction in pregnancy rate in the restricted group, which was accomplished with a 27% reduction in feed intake over the course of the restriction period, resulted in a 22% decrease in the quantity of feed consumed per pregnant heifer.

The best way to analyze the impact of energy restriction would be to sum all negative effects (lower pregnancy rate, etc.) and positive effects (reduced feed cost per pregnant heifer, etc.) from an energy restriction development program and compare those figures to see whether the cost savings is greater than the lost production. Unfortunately, in the study by Roberts et al. (2007), assigning economic values to these effects was not within the scope of the study. Therefore, it is unclear whether the marginal benefit of the reduction in feed costs was greater than the marginal cost of a reduction in pregnancy rates. If the marginal benefit is greater than the marginal cost, energy-restriction is the optimal heifer development program; if the marginal cost outweighs the marginal benefit, energy-restriction is a suboptimal solution.

In a study by Funston and Deutscher (2004), spring and summer-born breeding heifers were fed to achieve either 60% of mature body weight (high-gain group) or 55% of mature body weight (low-gain group) at breeding. Their reproductive performance through four parities was analyzed and heifers from the high-gain group were more expensive to develop and did not have a different level of reproductive performance.

Similar to restricting energy of developing gilts, it appears in the study by Funston and Deutscher (2004) that there was no statistically significant difference in reproductive performance between heifers fed a higher level of energy. In fact, because these dams are more expensive to produce, it can be reasoned restricting feed intake during development of female breeding stock could lead to an overall cost savings.

Stalder et al. (2000) performed an experiment where feed intake of gilts during development was restricted. The gilts in this study were fed three different diets. Diets 1 and 2 were both fed to gilts on an ad libitum basis, but diet 1 was a high-protein diet (18% CP) formulated to maximize lean growth while diet 2 was a high-energy low-protein diet (13% CP) designed to build fat reserves. Diet 3, a high-protein diet (23% CP) created to slow the development of gilts, was restricted-fed to developing gilts at a rate of 1.8 kg/day from 82 kg of body weight until the gilts were 180 days of age. Gilts not detected in estrus by 260 days of age were culled, all others were bred.

There were no statistically significant differences observed between gilts fed different development diets for the number of pigs born per litter (including stillborn piglets), number of pigs born alive per litter, litter birth weight, number of pigs nursed, number of pigs weaned, or litter weaning weight (Stalder et al., 2000). Although the authors did not speculate on how costs would have been affected by development diets, it is logical to assume that feed costs would have been lower for the energy-restricted group because they consumed less feed, even with the higher level of crude protein in the energy-restricted ration. Because the feed restrictions during development did not have a negative effect on reproductive productivity, the restricted-fed gilts weaned a statistically similar amount of market pigs at a lower cost of production. Therefore, it should have been economically advantageous for producers to restrict the energy of developing gilts in Stalder et al. (2000).

Jorgensen and Sorensen (1998) fed gilts three diets: semi ad libitum (ad libitum access to feed twice a day for 30 minutes at a time), control (formulated according to Danish standards), or 75% intake of control. It was found that leg soundness scores were the poorest for animals fed the semi ad libitum ration which led to a higher rate of culling (48% cull rate) for semi ad libitum gilts vs. 26% cull rate for control pigs and a 21% cull rate for gilts fed a ration equivalent to 75% of control. Although cull rates reported from all treatment groups in this study are greater than industry standards, a low feeding intensity during development did not lead to a reduction in reproductive longevity in sows. Assuming feed costs were lower for energy-restricted gilts, energy-restricted females were less expensive to produce in their project. Therefore, the reduction in development costs would be economically advantageous to producers because it was not accompanied by a decrease in sow longevity.

Jorgensen and Sorensen (1998) also measured milk yield over four lactation periods and average litter size. Means for both traits did not differ statistically among any of the groups. However, average litter size tended to be smaller for the 75% of control group; but this difference was not statistically significant (P=0.14).

Kirshgessner, Roth-Maier, and Nuemann (1984) found gilts restricted to 70-75% of ad libitum intake during development tended to produce heavier first-parity progeny at birth (1.33 kg restricted vs. 1.20 kg ad libitum); however, restricted-fed gilts were in the development phase of growth for 45 days longer than ad libitum females. At second-parity, the piglets from restricted dams were heavier (1.60 kg restricted vs. 1.50 kg ad libitum; P=0.05). Additionally, second-parity lactation feed intake of energy-restricted gilts was 20% greater compared to ad libitum intake. The greater lactation feed intake led to an additional 1 kg of body mass gained prior to weaning by restricted progeny.

Restricted-fed gilts had a 45 day longer development time and consumed 20% more lactation feed, but the authors speculated that the heavier weaning weights led to a 40 kg reduction in feed needed for weaned pigs and estimated restricted females had a higher reproduction rate of 0.9 litters per gilt entering the development program. All of these differences would need to be accounted for in a budget analysis to determine whether the restricted program yields higher returns.

Le Cozler et al. (1998, 1999) restricted feed intake of gilts to 80% of appetite and found that litter birth weights and average weight of piglets were not different between groups. However, the total number of live pigs tended to be higher in gilts fed to appetite during development ($P<0.1$). All reproductive performance indicators were not statistically different between groups, which, given lower feed costs for energy-restricted gilts, should lead to lower breakeven selling price for restricted progeny.

Klindt, Yen, and Christenson (1999) fed developing gilts 3 rations: ad libitum intake from 13 to 25 weeks of age (Ad Libitum); ad libitum intake from 13 weeks of age until 100 kg body weight, then 90% of ad libitum intake (Control); and 74% of ad libitum intake from 13 to 25 weeks of age (Restricted). Results indicated no statistical difference in reproductive performance between groups through 30 days of gestation. However, when evaluating the reproductive performance as a function of feed consumed, energy-restricted sows produced 30% more live embryos per unit of feed consumed than Control gilts. This difference could, as the authors stated, "increase the efficiency of pork production."

In a study by Johnson et al. (2007), gilts from two genetic lines were fed either an ad libitum diet or a diet formulated to restrict energy to 75% of ad libitum intake. Production data from this study showed no differences between groups for number of piglets born, number of piglets born alive or number of weaned pigs. However, energy-restricted gilts tended to wean a greater number of pigs than gilts provided ad libitum intake of feed during development (9.78 weaned pigs per litter from energy-restricted females vs. 9.56 weaned pigs per litter from non-restricted dams). Additionally, total weaning weight of progeny from limit-fed gilts was greater than that of ad libitum gilts (118.8 lb. per litter restricted vs. 111.3 lb. per litter ad libitum; P=0.028). Assuming lower feed costs would lead to less development costs for energy-restricted females, a producer would have seen a cost-savings in this case without losing reproductive performance. This should cause a lower breakeven selling price of energy-restricted progeny than ad libitum progeny. The greater litter weaning weights seen in progeny from limit-fed dams would indicate a producer could enjoy a cost-savings during gilt-development and an increase in reproductive performance, meaning this development program would probably be economically advantageous to producers; however, without analyzing all production data in an enterprise budget format, these results are not known.

2.3 Summary of Literature Review

In most literature examining the biology of the development systems, restricting energy has no negative effects on reproductive performance. Because it is logical to assume limit-fed gilts are less expensive to produce than their ad libitum counterparts, an overall reduction in progeny breakeven selling price should be evident. However, the magnitude of this savings is not known. In the subsequent chapter, production parameters of each treatment group of the Johnson et al. (2007) study will be used in an enterprise budget to assign economic values to production differences. The next section discusses the methods used in developing gilts, describes the steps undertaken to formulate the enterprise budgets used in this research, and describes the simulation used to quantify volatility in commodity markets.

Chapter 3: MATERIALS AND METHODS

Chapter 2 reviewed the literature associated with energy restriction during breeding livestock development. The methods used to economically analyze the differences in gilt development systems are described in this chapter. First, the methods used to produce the breeding gilts evaluated in this study are reviewed.

3.1 Gilt Development System

The Department of Animal Science at the University of Nebraska-Lincoln conducted a multi-year study (Johnson and Miller, 2005; Johnson et al., 2007) that evaluated production differences in a 2x2 factorial arrangement using two separate half-sibling maternal lines (Large White-Landrace [LWxLR] and Nebraska Line 45 cross [L45X]). The LWxLR and L45X gilts were half-sibling as they were produced by dams that were artificially inseminated with semen of the same industry maternal line boars. Gilts entered one of two development programs: (1) ad libitum access to feed or (2) restricted-fed from approximately 123 days of age to approximately 226 days of age. The feed provided to gilts in the restricted group was formulated to be equivalent to 75% of the energy consumed by gilts with unrestricted access to feed, while intake of essential nutrients and minerals were held at constant levels between treatment groups as to provide daily recommended levels of nutrients to the animals.

After a minimum 2 estrus periods, gilts were artificially inseminated and limit-fed a standard corn and soybean meal-based gestation diet (13.8% CP, 0.66% lysine) until approximately 4 days pre-farrowing. If a gilt failed to express estrus in a timely fashion, she was culled from the herd. From 4 days pre-farrowing until weaning, each group received a standard lactation diet (18.5% CP, 1.0% lysine) until progeny were weaned at approximately 12 to 15 lb. or 21 days of age. Gilts from each group were then fed a standard diet (13.8% CP, 0.66% lysine) until they were rebred. At this time, if an animal was open or had mobility issues, they were culled from the experiment. This process was continued until the fourth parity at which data were collected and used to evaluate each combination of line and group by production parameters. Production record (e.g., number of pigs weaned, weaning weights, lactation feed intake) through four parities were recorded for each sow. These production data, along with input and output prices and other production assumptions, were used to construct the enterprise budgets used in this research project. The methods used to devise an enterprise budget to economically analyze production data are discussed in the next section.

3.2 Methods for Developing Enterprise Budget

An enterprise budget was created to estimate revenue and costs using production data from Johnson and Miller (2005) and Johnson et al. (2007) studies. The unit of measurement for the budget was an individual sow and the budget was organized into three main sections: gilt development, nursery and market pig production for the first four parities, and an output page summarizing the revenues and costs for the sow and her market pigs throughout their lifetime. In the development section, production parameters from the Johnson and Miller (2005) and Johnson et al. (2007) studies (e.g., average daily gain, feed intake, initial weight, ending weight, days spent in the development program) were used to estimate costs and returns to each development system by genetic line. Feed cost was determined from the average feed consumed by a developed gilt multiplied by the percentage of each feedstuff included in each diet, and multiplied by a unit price. Diets differed among development groups to ensure each treatment group was fed according to NRC requirements. Table 3.1 lists ration compositions for all rations used in the study. Included in the table are two development rations (Ad Libitum and Restricted), three sow rations (gestation, lactation, and recovery), and 12 market swine rations (3 starter [S 1-3], 4 grower [G 1-4], and 5 finisher [F 1-5]). The amount in pounds of each ingredient in one ton of mixed ration is listed for all 17 rations.

Table 3.2 contains input and output prices, and other production costs incurred during market pig production. Output price was the national net market pig price average of 2004-2006 monthly data compiled by Livestock Marketing Information Center multiplied by a constant dressing percentage of 74% to convert into a live basis for market pig selling price. The other output price included in Table 3.2 was cull sow selling price. Sow selling price was calculated as a percentage of market swine selling price to allow sow price to vary with market pig selling prices. The percentage value of culled sows in relation to market pigs was determined by dividing monthly historical national direct sow selling prices (300 to 449 lb. weight range; reported by Livestock Marketing Information Center) by national net market pig live selling price. Thus, the percentage value of culled sows to market pigs was calculated to be 74% of the market swine selling price.

Ingredient prices were included in Table 3.2 for major ration components such as corn, soybean meal, tallow, dicalcium phosphate, limestone, and salt. Corn price was an average of 2004-2006 monthly data, Omaha, NE basis, reported by Livestock Marketing Information Center. Soybean meal price was also an average of 2004-2006 monthly data reported by Livestock Marketing Information Center, but was basis central Illinois.

Table 3.1 Ration Compositions[1].

	Gilt Rations		Sow Rations			Market Swine Rations											
Ingredient	Developer (Ad Libitum)	Developer (Restricted)	Gestation	Lactation	Recovery	S 1	S 2	S 3	G 1	G 2	G 3	G 4	F 1	F 2	F 3	F 4	F 5
Corn	1547.5	1354.8	1545.1	1313.5	1545.1	852.5	1184.2	1367.5	1363.2	1367.7	1490.2	1482.7	1586.3	1583.9	1664.4	1487.2	1486.7
Soybean Meal	332	500	320.0	550.0	320.0	640.0	675.0	520.0	520.0	520.0	405.0	405.0	310.0	310.0	235.0	410.0	410.0
Tallow	60	60	60.0	60.0	60.0			60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Dicalcium Phosphate	29.5	47.5	38.0	46.5	38.0	20.0	33.0	25.0	14.0	14.0	7.0	7.0	5.0	5.0	2.5	7.0	7.0
Limestone	13	17	18.5	12.0	18.5	7.0	12.5	13.5	19.5	19.5	19.5	19.5	22.0	22.0	21.5	19.5	19.5
Salt	10	10	10.0	10.0	10.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
F-G-N Pre-Mix			5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	4.0	4.0
TM Pre-Mix	5.00	6.67	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0	3.0	3.0
Lysine	3.00	4.00	0.4	0.0	0.4		0.8	1.0	2.5	2.5	2.4	2.4	2.8	2.8	2.7	2.4	2.4
Phytase									0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
AUREO-50									7.4								
Safeguard										2.9				4.9			
Tylan-40											2.5		2.5		2.5		
Lincomycin-20												10.0					
Ractopamine																0.5	1.0
Dried Whey						300.0											
Fish Meal						80.0											
Corn Oil						60.0	60.0										
Mecadox (2.5 g/lb)						20.0	20.0										
Zinc Oxide						6.0											
DL - Methionine						0.5	0.5										

[1]Quantaties in lb. per ton of mixed ration

Table 3.2 Input and Output Prices for Market Pig Production per Unit[1].

Item	Price per Unit	Unit	Type of Expense	Cost per Pig	Cost per Litter
Market Pig Selling Price[2]	$49.68	/cwt	Veterinary and Health Cost	$4.72	
Cull Sow Selling Price[2]	$36.76	/cwt	Utilities	$1.57	
Corn	$2.14	/bu	Marketing and Transportation Costs	$1.68	
Soybean Meal	$199.79	/ton	Other Misc. Costs		$10.00
Tallow	$0.29	/lb	Labor		$62.28
Dicalcium Phosphate	$220	/cwt	Annual Fixed Costs (per pig-space)	$18.24	
Limestone	$0.02	/lb	Annual Fixed Costs (per sow-space)		$79.30
Salt	$0.07	/lb	Breeding Costs		$20.00

[1]Prices From 2004-2006

[2]Live Weight Basis

3.2.1 Gilt Development Program Budget

Several steps were used to calculate the total costs of gilt development. The initial cost of a gilt entering the development program was calculated by multiplying the average beginning weight of gilts entering the program by 110% of the market pig selling price (shown on Table 3.2). The reasoning behind the 10% upward adjustment was to account for a feeder pig price slide because gilts entering the development programs were approximately 140 lb., thus would have more value on a per unit basis than a market pig.

Additionally, an adjustment was made to the initial purchase price to account for culled gilts and gilts that died while in the development program. The calculations for gilt purchase cost are illustrated as follows:

$$GC = MPSP \times 110\% \times ABW \times (1 + C\% + D\%) \tag{3.1}$$

where *GC* = purchase cost of gilt ($ per developed gilt)
MPSP = market pig selling price ($ per live lb.; Table 3.2)
ABW = average body weight (live basis, lb.)
C% = cull percent (%)
D% = death percent (%)

Cull credits were calculated by multiplying the cull percentage of gilts during development (because the budget is on an individual sow unit of measurement) by an average weight for gilts from each treatment group and genetic line and the market pig selling price (because culled gilts were priced as market pigs). Because gilts were not culled until after the development program, cull weights are equal to the weight at parity one breeding.

Veterinary expense, utilities, and miscellaneous costs were based on Lawrence and Ellis (2007) and were estimated at $5, $2, and $4/gilt, respectively. To account for production expenses consumed by culled and dead gilts, adjustments were made to find the final costs. Assuming all deaths occurred at the midpoint of the development period and remembering that females were culled at the end of the development period, these costs were multiplied by a factor of $1 + \textit{cull}\ \% + 1/2 \times \textit{death}\ \%$. After these adjustments, these figures reflect the veterinary expense, utilities, and miscellaneous costs incurred in gilt production.

It was assumed that one hour of labor would be needed for each gilt produced. An agricultural labor wage rate of $10.53/hour was obtained from the United States

Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) (2009). As was done with previous production costs, an adjustment was made to account for labor used by culled and deceased gilts by multiplying the base labor cost of $10.53/gilt by a factor of *1+ cull % + 1/2× death %*.

Interest expense was calculated in a two-step process. First, variable production costs (feed cost, veterinary expense, utilities, miscellaneous cost, and labor) of gilt development were summed and multiplied by an assumed annual interest rate of 7%. This number is then multiplied by the development time period after it was converted to a yearly basis. Because production costs were assumed to be incurred at a constant rate, the interest amount calculated above is then halved. Second, the interest from the purchase cost of gilt was calculated by multiplying the purchase cost of gilt (*GC*) from equation 3.1 by the assumed interest rate of 7%, and then by the time the gilt spent in the development program in years. Lastly, the interest from the purchase of the gilt is added to the interest on production costs. Thus, interest cost is calculated by the following equation:

$$IE_G = (PC_G \times 0.07 \times T_G \times 1/2) + (GC \times 0.07 \times T_G) \quad (3.2)$$

where IE_G = interest expense from gilt development ($/head)
PC_G = production costs of gilt development ($/head)
GC = purchase cost of gilt ($ per developed gilt; from equation 3.1)
T_G = interest time period of gilt development (years)

The final variable cost included in the enterprise budget was overhead and management. These costs were based on industry estimates and were calculated to be 2% of operating costs for all treatment groups.

Building and equipment costs were calculated based on costs from Lawrence and Ellis (2007). Because gilts were developed in a finishing facility, the facilities cost of a finisher was used when calculating fixed costs during gilt development. Lawrence and Ellis' budgets assume a 9,600 head finisher would have an equipment cost of $570,000 with a useful life of 10 years; the building cost of the finisher was assumed to be $1.33 million with a useful life of 25 years. The total building and equipment cost was then divided by its useful life to give an annual facilities cost. This annual cost was then divided by the capacity of the building to give an annual facilities cost on a per animal basis, then multiplied by the time the gilt spent in the gilt development period to give a building and equipment cost on a per gilt basis. This amount is then adjusted by multiplying it by a factor of *1+ cull % + death %* to account for facilities that were occupied by culled and deceased gilts. To account for interest, annual repairs, insurance, and taxes on the facilities, the facilities cost was multiplied by 109.6% (7% for interest, 1.5% for annual repairs, 0.4% for property insurance, 0.7% for property tax; Lawrence and Ellis, 2007). Finally, this figure was multiplied by the amount of time the gilts spent in the development program. This process is illustrated as follows:

$$FC = ([\{BC / UL_B\} + \{EC / UL_E\}] / CAP) \times T \times 1.096 \qquad (3.3)$$

where FC = facilities cost
BC = building cost
UL_B = useful life of building
EC = equipment cost
UL_E = useful life of equipment
CAP = building capacity (pigs)
T = time spend in development program (years)

3.2.2 Market Pig Budget

The next section of the budget itemized production costs from nursery and market pig production. This section included production parameters similar to those in the development section (e.g., average daily gain, feed intake), but also included 3 sow and 12 market pig feed rations (Table 3.1). The amount of feed consumed by sows during gestation was estimated to be 490 lb. per bred female: 460 lb. of the gestation ration and 30 lb. of the lactation ration. Gestation feed intake was calculated as pregnant females were limit-fed specific daily amounts: 4 lb. per day for the first 90 days, 5 lb. per day for the next 20 days, 6 lb. per day of the lactation ration for the final 5 days of gestation. An adjustment was made to gestation feed intake to account for females that were bred, but later culled due to miscellaneous reasons. Because these females were culled at an average of 50 days into the gestation period, it was assumed each culled gilt consumed 200 lb. of feed (4 lb./day for 50 days) before they were sold. Additionally, deceased sows were assumed to have died an average of 50 days into the gestation cycle as well, and would have consumed 200 lb. of feed before they expired. This adjustment to gestational feed intake is illustrated below:

$$GFI = 490 + [200 * (C\% + D\%)] \qquad (3.4)$$

where GFI = gestational feed intake (lb. per litter)
$C\%$ = cull percentage of sows at current parity (%)
$D\%$ = death loss percentage of sows at current parity (%)

Feed intake during lactation was recorded by Johnson and Miller (2005) and Johnson et al. (2007) for each sow during repetition 4 of their experiment. These individual totals were averaged by genetic line and treatment for use in the production budget. Table 3.3 below contains a list of these averages.

Table 3.3 Lactation Feed Intake by Line and Treatment[1].

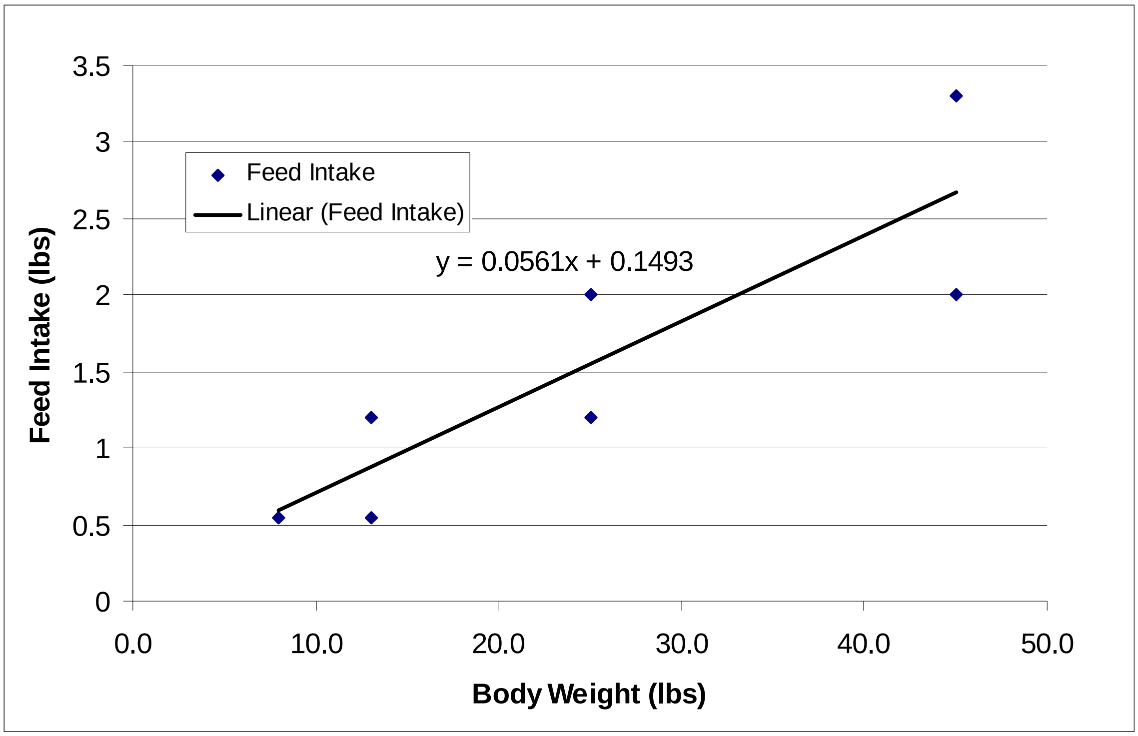
Lactation Period	Line			
	LWxLR		L45X	
	Ad Libitum	Restricted	Ad Libitum	Restricted
Parity 1	138.30	140.90	154.09	151.02
Parity 2	208.77	215.33	217.29	213.13
Parity 3	200.24	196.19	230.05	207.36
Parity 4	195.24	196.56	211.35	193.26

[1]Amounts are in lb. per sow

Post-weaning and before rebreeding the sows were fed the same ration as during the gestation period. During this recovery period, feed intake was estimated to be approximately 4.08 lb. per day per female. This number was calculated based on Johnson’s assumption that 85% of sows were in good physical condition and therefore required 4 lb. of feed per day (2009). The remaining 15% of sows were considered “light” by the researchers and needed an additional 0.5 daily lb. of feed. Thus, these “light” sows required 4.5 lb. of feed per day (Johnson, 2009). The average amount of feed consumed during the recovery period per litter was calculated by finding the amount of feed consumed daily by both groups and multiplying each amount by the percentage of sows in that group, then summing those totals and multiplying this amount by the number of days sows spent in recovery.

Feed intake by market swine was recorded for 240 pigs during the experiment, 120 of each genetic line. However, this intake was only recorded when pigs were 40 to 260 lb. Therefore, a feed intake curve was estimated to approximate intake of progeny from weaning (approximately 11 lb.) to 40 lb. of body weight. The growth curve was estimated based on data from Reese et al. (2000), in which feed intake of market swine was estimated at seven body weight intervals. The first three of those body weight intervals were from 8 to 13, 13 to 25, and 25 to 45 lb. of body weight, respectively. Daily feed intake was estimated to be 0.55, 1.2, and 2.0 lb. of feed/day at each of the three intervals, respectively. The three intervals correspond to the weight range for which data on feed intake was not recorded, and therefore, needed to be estimated. A graph of the data points and the best-fit line is included below as Figure 3.1.

Figure 3.1 Growth Curve Approximation.



Next, the formula for the best-fit line ($y = 0.0561 \times (x) + 0.1493$, where y = feed intake in lb. and x = body weight in lb.) was used to calculate feed intake at each body weight (in 1 lb. increments) from 11 lb. (weaning) to 40 lb. (approximately 60 days of age). The results were then aggregated into the three weight ranges mentioned above (8 to 13 lb., 13 to 25 lb., and 25 to 45 lb.), each of which corresponded to a starter diet, which gave daily feed intakes of 0.74, 1.22, and 2.11 lb. per day for each weight range, respectively.

Because, as previously mentioned, each weight range coincided to a starter ration used in the Johnson and Miller (2005) and Johnson et al. (2007) studies, the amount of time each ration was fed was as follows: 7 days each for starters 1 and 2, and approximately 32 days (until 60 days of age) for starter 3. Thus, each average daily feed intake was multiplied by the time the progeny consumed each ration, which gave an average feed intake by ration as follows: 5.17 lb. of starter 1, 8.51 lb. of starter 2, and 67.61 lb. of starter 3. Because these estimations approximated feed intake from 8 to 45 lb. of body weight, they needed to be adjusted to estimate feed intake from 11 to 40 lb. of body weight. Assuming a constant feed conversion ratio of 0.385 lb. of growth per lb. of feed consumed (Johnson et al., 2007), the estimation from the growth curve equation was approximately 7% overstated as the average body weight would be 42.3 lb. Making the 7% reduction to average feed consumption per pig by ration type gave the following approximate feed intakes: 4.81 lb. of starter 1, 7.91 lb. of starter 2, and 62.88 lb. of starter 3.

On average, weaning weights among treatment groups were statistically different. Thus, each line × treatment × parity interaction led to a different amount of feed consumed by litter. Therefore, feed consumption by ration type was adjusted to account for differences in weaning weights between the 16 line × treatment × parity interactions. This was accomplished by finding the percentage of feed intake by an average pig of each ration and calculating the feed efficiency ratio (lb. of gain per lb. of feed consumed), holding the ratio constant to find the amount of feed the comparison group would need to reach market weight, and multiplying the ration percentage by the total amount of feed the pig consumed.

The amount of feed consumed during market pig production was itemized by diet ingredient in a four-step process. First, the percentage of diet composition was calculated for each ingredient. Second, the ingredient percentage was multiplied by the total amount of feed consumed of each ration. Third, these ingredient amounts were summed and the resulting quantities were multiplied by the price of each feedstuff. Lastly, the partial feed costs by ingredient were summed to give a total cost of feed during market pig production.

Non-feed variable costs were calculated next in the budget. These costs are based on numbers from Lawrence and Ellis (2007). Veterinary expense, utilities, and miscellaneous costs were $10, $3, and $6/litter during the gestation and lactation periods, respectively, and an additional $4.72, $1.57, and $1/market pig produced. Marketing/transportation costs and breeding costs were assumed to be $10 and $20/litter, respectively (Lawrence and Ellis, 2007).

Similar to calculating labor costs in gilt development, an agricultural labor wage rate of $10.53/hour from United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) (2009) was used when calculating labor costs. It was assumed that two hours of labor would be needed during gestation and lactation per litter and an additional four hours of labor would be needed for market pig production per litter.

Interest expense was calculated by summing all variable production costs incurred during market pig production (feed cost, veterinary expense, utilities, miscellaneous cost, marketing/transportation cost, labor) and multiplying that number by an assumed annual interest rate of 7%. This number is then multiplied by the amount of time market pigs spent in the production program after it was converted to a yearly basis. Because costs were assumed to be incurred at a constant rate, the interest amount calculated above is then halved. This process was illustrated below in equation 3.5.

$$IE_{MP} = (PC_{MP} \times 0.07 \times T_{MP} \times 1/2) \tag{3.5}$$

where IE_{MP} = interest expense of market pig production
PC_{MP} = market pig production costs
T_{MP} = market pig interest time period (years)

Building and equipment costs were calculated based on costs from Lawrence and Ellis (2007). They assumed a 1,200 head gestation/farrowing barn would have an equipment cost of $546,000 and a building cost of $1.104 million. All equipment and buildings in their budget were assumed to have useful lives of 10 and 25 years, respectively. A 4,000 head nursery was assumed to have an equipment cost of $157,500 while the building cost of the nursery was assumed to be $292,500. The building cost of a 9,600 head finisher facility was assumed to be $1.33 million; whereas, equipment cost of the finisher was assumed to be $570,000. As was done when calculating gilt development costs, the total building and equipment cost was then divided by its useful life to give an annual facilities cost. This annual cost was then divided by the capacity of the building to give an annual facility cost on a per animal basis, then multiplied by the time period to give a building and equipment cost. These ownership costs were calculated on a per litter basis for the gestation, lactation, and recovery periods, and on a per market pig basis for ownership cost incurred due to market pig production. To account for interest, annual repairs, insurance, and taxes on the facilities, the facilities cost was multiplied by 109.6% (7% for interest, 1.5% for annual repairs, 0.4% for property insurance, 0.7% for property tax) (Lawrence and Ellis, 2007). Finally, this figure was multiplied by the amount of time the pig spent in each respective building. This process was illustrated previously in equation 3.3.

Income from market swine production can be divided into four categories: manure credits, market pig sales, culled gilt/sow sales, and culled pig sales. Manure credits were assumed to be a constant $25/litter produced. Manure credits did not vary between treatment$\times$line$\times$parity interactions because the quantity and quality of manure was not recorded and estimating variations between groups would have introduced additional bias to the model. Income from market pig production was calculated by multiplying the number of pigs weaned per litter by the factor of *1-cull %-death %* and by the average market weight. The resulting quantity of market pigs was then multiplied by the national net market price in $/lb (on a live-weight basis; Table 3.2) to give the total income of market pig sales.

The income from culled sows needed to fluctuate with market pig selling prices to replicate the real-world relationship between these prices. Thus, the cull sow price used to calculate the value of culled sow was found as a percentage of market pig selling price that sows have sold for historically. This percent (74%) was then multiplied by the market pig selling price to give a cull sow selling price in $/lb (on a live-weight basis; Table 3.2). Next, this price was multiplied by the average sow weight for the parity in which it was culled. In a similar manner, the value of culled pigs was calculated by assuming cull pig selling price was 50% of market pig selling price. Additionally, the weight of culled pigs was assumed to be 70% of market pig selling weight. The culled pig selling price was then multiplied by the cull pig weight to give a total value for culled market pigs.

Each of the results calculated above gave results on a parity-specific basis. Thus, a simple summation of costs and revenues from all parities would not be sufficient for reporting results for an average gilt for each treatment × line interaction because the probability of each event differed between treatment groups and among genetic lines. Therefore, to compute results, each cost and revenue was multiplied by the probability an average gilt would complete the outcome successfully. These outcomes were gilt development, gilt through first parity of market pigs, gilt through second parity, gilt through third parity, and gilt through fourth parity. To reiterate what was said previously: the probability of each of these outcomes was used to determine the weighted average revenue, costs, and profit for an average gilt entering the program. These probabilities are summarized below in Table 3.4.

Table 3.4 Event Probabilities for Two Prolific Maternal Lines.[1]

	Line			
	LWxLR		**L45X**	
Outcome	**Ad Libitum**	**Restricted**	**Ad Libitum**	**Restricted**
Parity 1 Litter	0.7714	0.7910	0.8695	0.8152
Parity 2 Litter	0.4581	0.5298	0.4846	0.5477
Parity 3 Litter	0.3848	0.4140	0.3841	0.4697
Parity 4 Litter	0.2888	0.3265	0.3242	0.3610

[1]Event probabilities based on successful completion of development program

There were two exceptions to the calculations mentioned above. These exceptions were when approximating sow cull credits and breeding costs. Sow cull credits were calculated differently because sows were not culled after their last successful parity. Instead, sows were culled on average 50 days into the next parity's gestational period. Thus, parity-specific cull credits were multiplied by the probability the sow successfully farrowed the litter before the sow was culled, then summed to give a total amount.

In a similar manner, breeding costs were incurred for all sows that successfully farrowed the previous litter. Therefore, parity-specific breeding costs were multiplied by the probability the sow successfully farrowed the previous litter. These partial costs were then summed to give a total amount of breeding cost incurred over the course of an average sow's lifetime.

3.3 Methods for Developing Simulation

The previous section described methods involved in creating the budget framework for which production data would be economically analyzed to compare different gilt development systems. This section describes methods used to create a simulation to further evaluate different development programs.

Chapter 1 discussed the need for an economic analysis to account for variations in commodity prices. The volatility of commodity markets causes variability in returns to gilt development programs. Thus, a deterministic analysis would be unable to properly analyze differences in gilt development programs under varying market conditions. The budget analysis simply inserted average data points for corn, soybean meal, and market pig prices to give a point comparison between gilt development systems using historical data. However, this method is not adequate for comparing the economics between ad libitum and energy-restricted gilt development systems because it is purely a deterministic result. Therefore, to quantify the variability of returns between gilt development systems caused by commodity market volatility, a stochastic simulation of the budget was needed. Thus, variations in prices of corn, soybean meal, and market pigs would be accounted for in the results. The Excel-based program, Simitar, was used to create the stochastic simulation experiment because this program can test data distributions, simulate price series, and create cumulative distribution functions for analysis (Richardson, 2005).

The first step was to collect historic data on price series to determine relationships between data sets. Monthly historical average prices of Omaha cash corn, Central Illinois soybean meal and national net market pig selling prices compiled by Livestock Marketing Information Center were used. To account for inflation, these prices were converted into real prices by multiplying the nominal price by the following:

$$CPI_{Base} / CPI_{Current}$$

where CPI_{Base} = consumer price index core inflation in the base month (October 2009)
$CPI_{Current}$ = consumer price index core inflation in the comparison month

After nominal prices were deflated, the covariance between each price series was calculated using Simitar. These summary statistics (means and covariances) of each real price series are included below in Table 3.5.

Table 3.5 Summary Statistics of Input and Output Prices.

	Means	Covariances		
		Corn Price	Soybean Meal Price	Market Pig Price[1]
Corn Price	3.018	1.288	57.348	4.024
Soybean Meal Price	244.151	57.348	4448.939	277.680
Market Pig Price[1]	51.544	4.024	277.680	110.120

[1]Live Basis

Real price series were each graphed in histograms (Figures 3.2-3.4) to visualize the characteristics of the data and determine which method of simulation was appropriate (discrete vs. continuous, normal vs. empirical, etc.).

Figure 3.2 Corn Price Histogram.

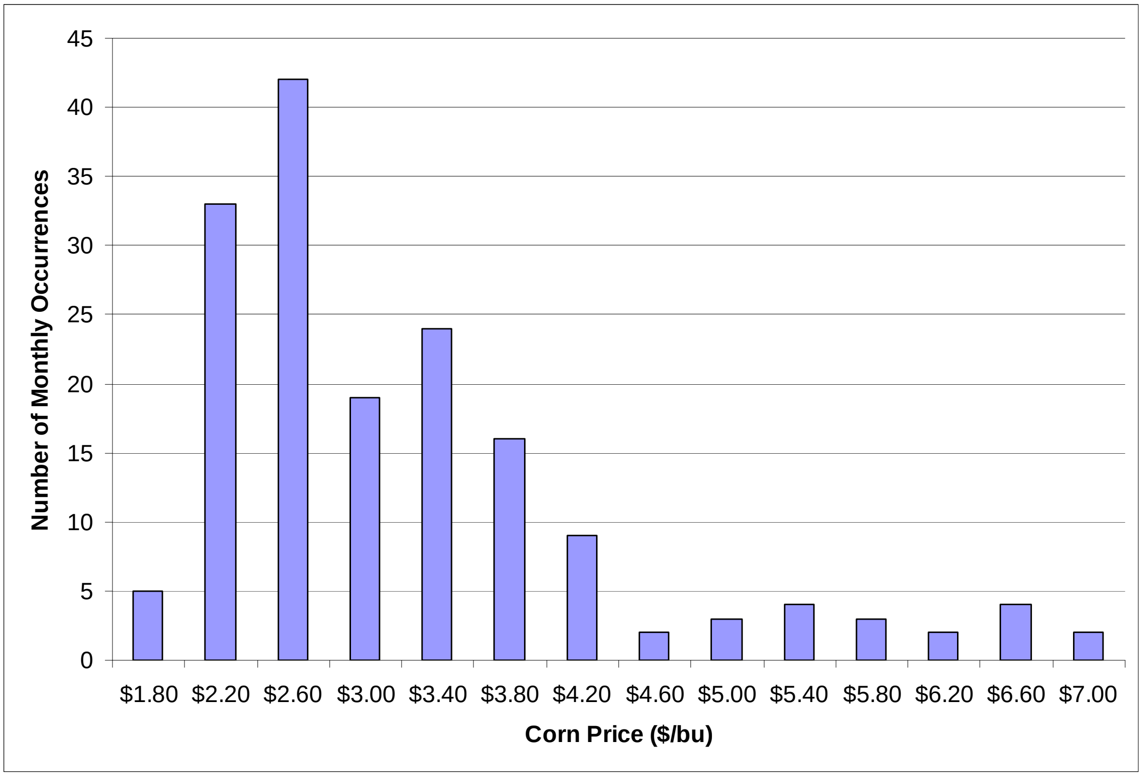


Figure 3.3 Soybean Meal Price Histogram.

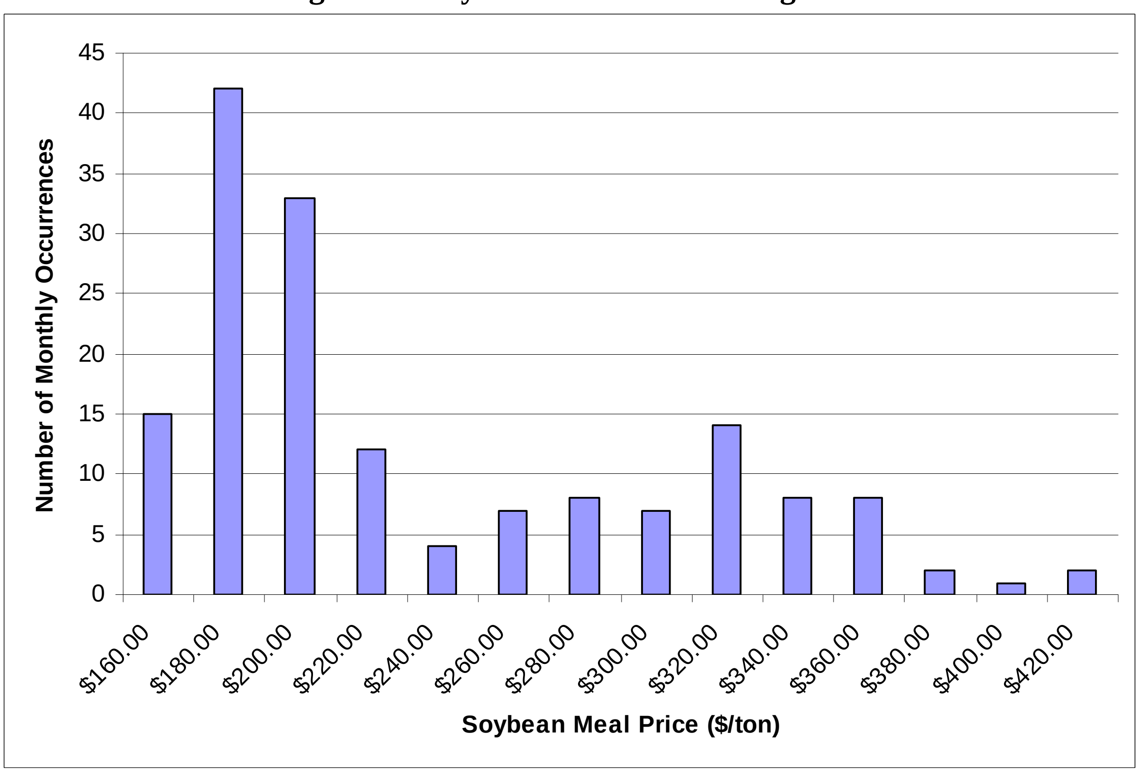
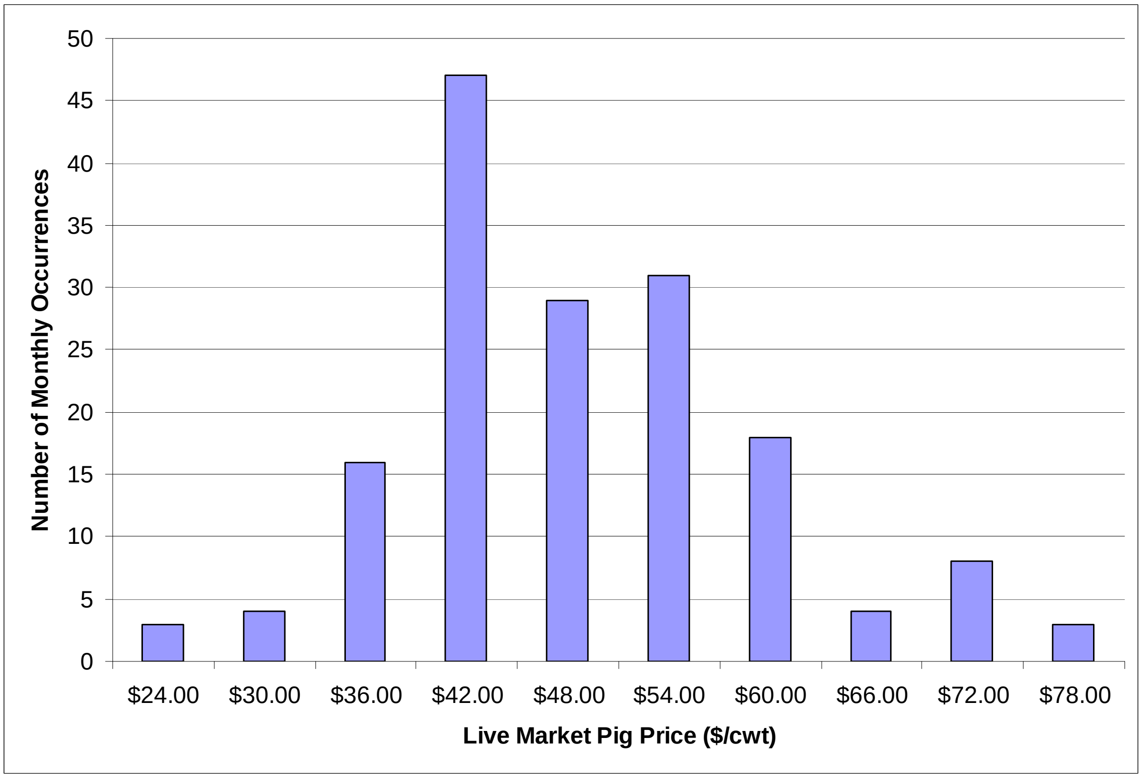


Figure 3.4 Live Market Pig Selling Price Histogram.



Even though the data did not appear to be normally distributed in Figures 3.2-3.4, four tests of normality were performed in Simitar to statistically test for a normal distribution. The four tests were the Shapiro-Wilk test (S-W), the Anderson-Darling test (A-D), Cramér-von-Mises criterion (CvM), and the chi-squared test (Chi-Squared). This is important in the model-building procedure because if data were incorrectly assumed to be normally distributed, the model formulated based on the normality assumption would be biased and, therefore, not the best-fit model. The results of the normality test are given on Tables 3.6, 3.7, and 3.8 below.

Table 3.6 Test for Normality of Distribution for Corn Price Series.

Procedure	Test Value	P-Value[1]	
S-W	0.838	4.53E-12	*Reject Ho that the Distribution is Normally Distributed*
A-D	8.213	4.49E-20	*Reject Ho that the Distribution is Normally Distributed*
CvM	1.333	3.65E-10	*Reject Ho that the Distribution is Normally Distributed*
Chi-Squared	105.621	1.14E-18	*Reject Ho that the Distribution is Normally Distributed*

[1]95% Confidence Level

Table 3.7 Test for Normality of Distribution for Soybean Meal Price Series.

Procedure	Test Value	P-Value[1]	
S-W	0.869	1.20E-10	*Reject Ho that the Distribution is Normally Distributed*
A-D	8.532	7.98E-21	*Reject Ho that the Distribution is Normally Distributed*
CvM	1.576	7.95E-10	*Reject Ho that the Distribution is Normally Distributed*
Chi-Squared	103.957	2.49E-18	*Reject Ho that the Distribution is Normally Distributed*

[1]95% Confidence Level

Table 3.8 Test for Normality of Distribution for Market Pig Price Series.

Procedure	Test Value	P-Value[1]	
S-W	0.967	6.88E-4	*Reject Ho that the Distribution is Normally Distributed*
A-D	1.859	9.11E-5	*Reject Ho that the Distribution is Normally Distributed*
CvM	0.295	3.73E-4	*Reject Ho that the Distribution is Normally Distributed*
Chi-Squared	15.509	7.79E-2	*Fail to Reject Ho that the Distribution is Normally Distributed*

[1]95% Confidence Level

The price series were proven to be statistically different from normally distributed data in all normality tests in Tables 3.6 and 3.7. In Table 3.8, the Chi-Squared test shows a P-value of 0.079 which would signify a failure to reject the null hypothesis at the 0.05 significance level. However, in all of the other 3 tests of normality one could reject the null hypothesis at the 0.01 significance level and, in the Chi-Squared the null hypothesis can be rejected at the 0.1 significance level. Thus, the price series data were concluded to not be normally distributed.

Because one would assume the prices of corn, soybean meal, and market pigs would be correlated, any price simulation would need to reflect these relationships. Using multivariate techniques to generate price series accounts for the correlation between price series. According to Richardson (2005), if the correlation between two random variables is ignored in a simulated model, the variance of the model would be biased in an inverse relation to the previously stated correlation. Therefore, two tests were performed in Simitar to test for a normal multivariate distribution. The two tests were Skewness (a test of asymmetry), which statistically tests if the multivariate skewness statistic is different from the skewness statistic of a normal series, and Kurtosis (a test of extreme deviations) which statistically compares the kurtosis statistics of the price series with that of normally distributed data.

The results of this test are as follows in Table 3.9.

Table 3.9 Test for Normality of a Multivariate Distribution.

Procedure	Test Value	Critical Value[1]	P-Value	
Skewness Criterion	133.777	18.307	7.91E-24	*Reject the Ho that the Data Are Multivariate Normally Distributed*
Kurtosis Criterion	4.366	1.960	6.34E-08	*Reject the Ho that the Data Are Multivariate Normally Distributed*
Chi-Squared Quantile Correlation	0.977			

[1]95% Confidence Level

As was illustrated in Table 3.9, the three historical price series were not normally distributed because the null hypothesis was able to be rejected (H_O : the data are multivariate normally distributed) according to the Skewness Criterion (P=1.22E-27) and the Kurtosis Criterion (P=2.87E-08). Thus, the historical price series are not multivariate normally distributed and using a system that creates three normally distributed price series would not be appropriate. Therefore, the price simulations used in this study were created using a multivariate empirical distribution.

An empirical distribution is closed form, and thus has finite minimum and maximum values, unlike a normal distribution where the upper and lower bounds are positive and negative infinity, respectively. The empirical distribution is discrete, but interpolation between data points allows the cumulative distribution function to be continuous.

The Simulation Engine function of Simitar (Richardson, 2005) was used to generate prices that possessed means and correlations statistically similar to actual historical prices. The summary statistics comparing historical prices series and those generated by the Simulation Engine function are in Tables 3.10 and 3.11.

Table 3.10 Summary Statistics of Historical and Generated Data Series.

Generated Data				
	Means		Covariance	
Corn	3.007	1.250	53.308	4.201
Soybean Meal	243.552	53.308	4414.646	285.347
Market Pig (Live Basis)	51.525	4.201	285.347	101.704
Historical Data				
	Means		Covariance	
Corn	3.018	1.288	57.348	4.024
Soybean Meal	244.151	57.348	4448.939	277.680
Market Pig (Live Basis)	51.544	4.024	277.680	110.120

Table 3.11 Distribution Comparison.

	Test Value	Critical Value[1]	P-Value	
2 Sample Hotelling T^2 Test	0.27	7.94	1.000	*Fail to Reject Ho that the Mean Vectors are Equal*
Box's M Test	1.47	12.59	0.961	*Fail to Reject Ho that the Covariance Matrices are Equivalent*
Complete Homogeneity Test	1.50	16.92	0.997	*Fail to Reject Ho that the Mean Vectors and Covariance Matrices are Equivalent, Respectively*

[1]95% Confidence Level

As was illustrated in Table 3.10 and Table 3.11, the historical and generated price series are statistically similar because one would fail to reject a difference in means (P=1.000), covariances (P=0.961), or means and covariances (P=0.997) between the price series at any significance level. Therefore, the historical price series is statistically similar to the generated price series. Thus, the Simulation Engine could be used to generate appropriate price data in a simulation experiment.

Because the simulated data were statistically similar to the historical data, the Simulation Engine function was used to generate 1000 iterations of price data which were separately inputted into the budget. The profit/loss and breakeven selling price of progeny were recorded for treatment$\times$line interactions. Next, two cumulative distribution functions were created for each line from the data (one of profit/loss, one of breakeven selling price) to illustrate differences between treatment groups. These results are reported and analyzed in Chapter 4.

3.4 Summary

Chapter 3 described the methods used to create an enterprise budget capable of economically analyzing energy-restriction during gilt development. This chapter also described the simulation used to quantify commodity market volatility by comparing total profit/loss and breakeven selling price of progeny for each treatment group by genetic line interaction. Chapter 4 will report the results of the budgetary and simulation analyses.

Chapter 4: RESULTS

Chapter 3 described the methods used to formulate an enterprise budget to evaluate different gilt development systems and the Simitar simulation experiment used to quantify variability of returns. In this chapter, the results from the budget analysis and the simulation will be reported and discussed. First, the results from the budget are presented.

4.1 Budget Results

Section 3.2 described the methods used when formulating the enterprise budget used to economically analyze production differences in gilt development systems. The results from the enterprise budget analysis generally revealed that energy-restricted gilts produced a greater amount of offspring and were more profitable than their ad libitum counterparts.

An average ad libitum and restricted LWxLR gilt produced 17.8 and 19.7 marketed offspring, respectively. The ad libitum LWxLR gilt and her litters consumed a total 14,551 lb. of feed valued at $1,049.09 while an energy-restricted LWxLR gilt and her progeny consumed 15,846 lb. of feed with a total feed cost of $1,148.64 (Table 4.1). An energy-restricted LWxLR gilt and her progeny consumed a greater amount of feed because of the increased reproductive production of the restricted gilt. Non-feed variable costs totaled $615.23 and $670.38 for an average ad libitum and restricted LWxLR gilt, respectively (Table 4.1). Ownership costs for ad libitum and restricted LWxLR gilts totaled $299.73 and $328.23, respectively (Table 4.1). Overhead and management costs totaled $33.29 and $36.38 for an average ad libitum and restricted LWxLR gilt, respectively (Table 4.1). Total credits, including cull credits for sows and pigs as well as manure credits, totaled $208.99 and $229.66 for ad libitum and restricted LWxLR gilts, respectively (Table 4.1). Summing all production costs from gilt development and market pig production resulted in a total cost of $1,788.34 for an average ad libitum LWxLR gilt and her market pigs and $1,953.96 for an average restricted female and her market pigs.

An average ad libitum L45X gilt and her 19.1 marketed offspring consumed a total of 15,606 lb. of feed with a total feed cost of $1,125.73 while an average restricted L45X female produced 20.3 marketed progeny and they consumed 16,340 lb. of feed totaling $1,183.96 (Table 4.1). Non-feed variable costs totaled $626.72 and $665.01 for ad libitum and restricted L45X gilts, respectively (Table 4.1). Ownership costs for an ad libitum L45X gilt and her progeny totaled $320.50, while an average restricted female had an ownership cost of $339.59 (Table 4.1). Overhead and management costs for an average ad libitum and restricted L45X gilt totaled $35.05 and $36.98, respectively (Table 4.1). Total credits (cull credits for sows and pigs and manure credits) totaled $214.00 for ad libitum L45X gilts and $211.16 for their restricted counterparts (Table 4.1). Summing all costs resulted in a total cost of $1,894.01 for an ad libitum gilt and market pigs and $2,014.37 for an average restricted female and her market pigs.

Table 4.1: Market Pig Production Summary.

			LWxLR						L45X					
			Ad Libitum Diet			**Restricted Diet**			**Ad Libitum Diet**			**Restricted Diet**		
			Sow with litter fed to 260 lbs			**Sow with litter fed to 260 lbs**			**Sow with Litter**			**Sow with Litter**		
				17.8	**pigs sold/sow**		**19.7**	**pigs sold/sow**		**19.1**	**pigs sold/sow**		**20.3**	**pigs sold/sow**
Feed (On Per Litter Basis)														
Corn	$2.14	/bu	11,694.7	lbs	$447.71	11,833.8	lbs	$453.03	11,694.7	lbs	$447.71	12,195.4	lbs	$466.88
Soybean Meal	$199.79	/ton	3,026.0	lbs	$302.27	3,109.9	lbs	$310.66	3,026.0	lbs	$302.27	3,204.7	lbs	$320.13
Tallow	$0.29	/lb	460.4	lbs	$133.52	467.2	lbs	$135.48	460.4	lbs	$133.52	481.7	lbs	$139.70
Dicalcium Phosphate	$0.22	/lb	101.2	lbs	$22.27	104.3	lbs	$22.94	101.2	lbs	$22.27	107.9	lbs	$23.73
Limestone	$0.02	/lb	149.5	lbs	$3.36	153.3	lbs	$3.45	149.5	lbs	$3.36	164.0	lbs	$3.69
Salt	$0.07	/lb	51.2	lbs	$3.58	51.6	lbs	$3.61	51.2	lbs	$3.58	54.7	lbs	$3.83
TM Pre-Mix	$0.24	/lb	20.7	lbs	$4.97	23.2	lbs	$5.58	20.7	lbs	$4.97	23.9	lbs	$5.73
Breeding Vitamin Pre-Mix	$0.29	/lb	5.5	lbs	$1.56	5.4	lbs	$1.54	5.5	lbs	$1.56	5.7	lbs	$1.61
F-G-N Pre-Mix	$0.69	/lb	24.2	lbs	$16.73	25.0	lbs	$17.23	24.2	lbs	$16.73	25.7	lbs	$17.72
Lysine	$0.73	/lb	16.1	lbs	$11.72	16.5	lbs	$12.08	16.1	lbs	$11.72	17.0	lbs	$12.41
Phytase	$1.92	/lb	2.4	lbs	$4.56	2.4	lbs	$4.70	2.4	lbs	$4.56	2.5	lbs	$4.83
AUREO-50	$1.61	/lb	3.8	lbs	$6.06	3.9	lbs	$6.24	3.8	lbs	$6.06	4.0	lbs	$6.42
Safeguard	$4.63	/lb	9.3	lbs	$43.04	9.6	lbs	$44.32	9.3	lbs	$43.04	9.8	lbs	$45.58
Tylan-40	$7.91	/lb	3.0	lbs	$23.48	3.1	lbs	$24.18	3.0	lbs	$23.48	3.1	lbs	$24.87
Lincomycin-20	$5.07	/lb	7.6	lbs	$38.70	7.9	lbs	$39.86	7.6	lbs	$38.70	8.1	lbs	$40.99
Ractopamine	$40.83	/lb	1.2	lbs	$48.49	1.2	lbs	$49.93	1.2	lbs	$48.49	1.3	lbs	$51.35
Dried Whey	$0.31	/lb	14.7	lbs	$4.55	13.0	lbs	$4.04	14.7	lbs	$4.55	15.5	lbs	$4.82
Fish Meal	$837.50	/ton	3.9	lbs	$1.64	3.5	lbs	$1.46	3.9	lbs	$1.64	4.1	lbs	$1.74
Corn Oil	$0.45	/lb	7.8	lbs	$3.50	8.2	lbs	$3.67	7.8	lbs	$3.50	8.2	lbs	$3.70
Mecadox (2.5 g/lb)	$1.43	/lb	2.6	lbs	$3.70	2.7	lbs	$3.89	2.6	lbs	$3.70	2.7	lbs	$3.92
Zinc Oxide	$0.60	/lb	0.3	lbs	$0.18	0.3	lbs	$0.16	0.3	lbs	$0.18	0.3	lbs	$0.19
DL - Methionine	$2.00	/lb	0.1	lbs	$0.13	0.1	lbs	$0.14	0.1	lbs	$0.13	0.1	lbs	$0.14
Total Ration in lbs			*14,551*	*lbs*		*15,846*	*lbs*		*15,606*	*lbs*		*16,340*	*lbs*	
Per Litter Feed Costs					$1,049.09			$1,148.64			$1,125.73			$1,183.96

Table 4.1: Market Pig Production Summary, continued.

Other Cash Costs (On Per Litter Basis)					
Initial Costs of Gilt		$95.07	$103.39	$84.94	$90.41
Veterinary and Health Costs		$111.44	$122.92	$119.13	$126.43
Utilities		$36.83	$40.64	$39.31	$41.73
Marketing and Transportation Costs		$29.94	$33.12	$32.15	$34.07
Feed Processing and Delivery		$72.75	$79.22	$78.03	$81.70
Breeding Costs		$52.29	$54.70	$41.25	$43.87
Misc. Operating Expenses		$34.95	$38.01	$37.24	$39.68
Labor	$10.53 /hr	12.4 hr $132.08	13.4 hr $143.47	13.4 hr $141.46	14.2 hr $150.66
Interest on Operating Expenses		$49.88	$54.90	$53.22	$56.46
Interest time period		21.0 months	22.7 months	22.7 months	24.2 months
Total Other Cash Costs (Per Litter Basis)		$615.23	$670.38	$626.72	$665.01
Ownership Costs					
Buildings and Equipment		$253.85	$278.53	$271.44	$288.06
Interest on Breeding Stock		$9.76	$9.90	$10.28	$10.38
Buildings and Equipment - Interest, Annual Repairs, Taxes, Insurance	9.60%	$36.12	$39.81	$38.78	$41.14
Total Ownership Costs (Per Litter Basis)		$299.73	$328.23	$320.50	$339.59
Overhead and Management (2% of operating costs)		$33.29	$36.38	$35.05	$36.98
Cull Credits					
Sows (Per Litter)		($135.70)	($149.68)	($134.83)	($127.06)
Pigs (Per Litter)		($25.71)	($28.45)	($27.61)	($29.26)
Manure Credits		($47.58)	($51.53)	($51.56)	($54.84)
Total Cost (Per Litter)		$1,788.34	$1,953.96	$1,894.01	$2,014.37

Results for each line and treatment are summarized on Table 4.2 in the form of revenue, variable costs, fixed costs, and total costs for gilt development and market pig production. Energy-restricted gilts were more productive than non-restricted females as they produced an average of 4.93 more cwts per developed LWxLR gilt (46.33 cwts sold per ad libitum gilt vs. 51.26 cwts sold per restricted gilt; Table 4.2) and 2.97 more cwts per developed L45X gilt (49.75 cwts sold per ad libitum gilt vs. 52.72 cwts sold per restricted gilt; Table 4.2). Thus, restricted gilts generated more revenue than ad libitum gilts by an average of $245.02 per LWxLR gilt ($2,301.61 per ad libitum gilt vs. $2,546.63 per restricted gilt; Table 4.2) and $147.63 per L45X gilt ($2,471.76 per ad libitum gilt vs. $2,619.39 per restricted gilt; Table 4.2). The increased production was primarily caused by energy-restricted females having a greater probability of farrowing a litter than an ad libitum gilt at each parity. An average energy-restricted LWxLR gilt had a greater probability of farrowing first, second, third, and fourth parity litters than ad libitum females (Table 3.4). Contrary to LWxLR gilts, an average energy-restricted L45X gilt did not have a greater probability of farrowing a first parity litter, but did have a greater probability of farrowing second, third, and fourth parity litters than an average ad libitum gilt (Table 3.4). However, in no case were these differences statistically significant. Additionally, as selling price increases, energy restriction during gilt development becomes more economically advantageous because, as previously mentioned, energy-restricted gilts produced a greater number of hundredweights than ad libitum gilts.

In addition to being more productive, limit-fed gilts were also less expensive to develop by an average of $9.74 for LWxLR females ($153.78 per ad libitum gilt vs.

$144.04 per restricted gilt; Table 4.2) and $7.58 per L45X gilt ($149.59 ad libitum vs. $142.01 restricted; Table 4.2). Although fixed costs were $0.73 greater per gilt for restricted LWxLR females ($6.64 ad libitum vs. $7.37 restricted; Table 4.2) and $0.53 per gilt more expensive for restricted L45X gilts ($6.21 ad libitum vs. $6.74 restricted; Table 4.2), this was more than offset by the large reduction in variable costs for energy restricted females. Variable costs were $10.47 lower per LWxLR gilt ($147.14 ad libitum vs. $136.67 restricted; Table 4.2) and $8.11 less expensive per L45 gilt ($143.38 ad libitum vs. $135.27 restricted; Table 4.2). Fixed costs during gilt development were greater for restricted gilts because gilts from this group were culled at a high rate than ad libitum gilts. Thus, to produce a gilt from each treatment group that successfully completes the development program, a greater number of restricted gilts are needed at the beginning than ad libitum females. Variable costs are lower because energy-restricted females consumed less feed than their ad libitum counterparts, even though the ration cost of energy-restricted feed was more expensive on a per ton basis than the ration fed to ad libitum gilts.

The market pig variable, fixed, and total costs of production were greater for progeny from energy-restricted gilts because of the greater reproductive production (more pigs) from those gilts. Variable costs of market pig production were an average of $147.60 greater for LWxLR gilts ($1,341.47 per ad libitum gilt vs. $1,489.07 per restricted gilt; Table 4.2) and $109.39 greater for L45X gilts ($1,430.13 per ad libitum gilt vs. $1,539.52 per restricted female; Table 4.2). Fixed costs were $27.77 greater per restricted LWxLR gilt ($293.09 per ad libitum gilt vs. $320.86 per restricted gilt; Table 4.2) and $18.55 greater per restricted L45X gilt ($314.29 per ad libitum gilt vs. $332.84

per restricted gilt; Table 4.2) because of the greater amount of building space needed to finish the restricted offspring. Summing these production costs showed that the progeny from an ad libitum gilt was less expensive to produce than the progeny from an energy-restricted female by an average of $175.37 for LWxLR gilts ($1,634.56 per ad libitum gilt vs. $1,809.93 per restricted female; Table 4.2) and $127.94 for L45X gilts ($1,744.42 per ad libitum gilt vs. $1,872.36 per restricted gilt; Table 4.2). However, as previously mentioned, one of the reasons the cost of market pig production is greater for progeny from energy-restricted gilts was because of the greater reproductive performance of these limit-fed females. Thus, one would expect total cost numbers to be greater for market pigs from these experimental treatment groups.

Summing total costs of gilt development and market pig production gave a total cost per sow which was lower for ad libitum gilts by an average of $165.62 for LWxLR gilts ($1,788.34 per ad libitum gilt vs. $1,953.96 per restricted female; Table 4.2) and $120.36 for L45X gilts ($1,894.01 per ad libitum gilt vs. $2,014.37 per restricted female; Table 4.2). Thus, even though energy-restricted females were less expensive to produce, this fact was outweighed by the increase in the cost of market pig production by the offspring of energy-restricted gilts.

The total profit/loss per gilt was calculated by subtracting the total cost per gilt of each treatment and genetic line from the total revenue generated by each line × treatment interaction. Energy-restricted gilts generated larger profits than their ad libitum counterparts by an average of $79.39 per LWxLR female ($513.28 per ad libitum gilt vs. $592.66 per restricted female; Table 4.2) and $27.27 per L45X gilt ($577.75 per ad libitum female vs. $605.02 per restricted gilt; Table 4.2).

On average, progeny from restricted fed LWxLR gilts had a $0.48/cwt lower breakeven selling price than ad libitum market pigs ($38.60/cwt ad libitum vs. $38.12/cwt restricted; Table 4.2). The lower breakeven selling price can be attributed to the increased production of energy-restricted gilts and also to the lower feed cost of limit feeding gilts during development. However, progeny from energy-restricted L45X dams had a $0.14/cwt higher breakeven selling price than progeny from non-restricted dams ($38.07/cwt ad libitum vs. $38.21/cwt restricted; Table 4.2). The majority of this effect was traced back to the large number of ad libitum females that were culled after producing their first litter. Additionally, because ad libitum gilts were heavier after successfully completing the development program, this led to an even larger cwt quantity of culled sows. Thus, the breakeven selling price of ad libitum LWxLR progeny was lower than for offspring from restricted LWxLR gilts.

Table 4.2 Revenue and Cost of Production for Two Prolific Maternal Lines.

	Line					
	LWxLR			L45X		
Item	Ad Libitum	Restricted	Difference[1]	Ad Libitum	Restricted	Difference[1]
Total cwts Produced per sow)[2]	46.33	51.26	4.93	49.75	52.72	2.97
Revenue (per sow)	$2,301.61	$2,546.63	$245.02	$2,471.76	$2,619.39	$147.63
Gilt Production (per gilt)						
Variable Costs	$147.14	$136.67	($10.47)	$143.38	$135.27	($8.11)
Fixed Costs	$6.64	$7.37	$0.73	$6.21	$6.74	$0.53
Total Costs	$153.78	$144.04	($9.74)	$149.59	$142.01	($7.58)
Market Swine (per litter through 4 parities)						
Variable Costs	$1,341.47	$1,489.07	$147.60	$1,430.13	$1,539.52	$109.39
Fixed Costs	$293.09	$320.86	$27.77	$314.29	$332.84	$18.55
Total Costs	$1,634.56	$1,809.93	$175.37	$1,744.42	$1,872.36	$127.94
Total Cost (per sow)	$1,788.34	$1,953.96	$165.62	$1,894.01	$2,014.37	$120.36
Profit/Loss (per sow)	$513.28	$592.66	$79.39	$577.75	$605.02	$27.27
Breakeven Selling Price (per cwt)[2]	$38.60	$38.12	($0.48)	$38.07	$38.21	$0.14

[1] Restricted minus Ad Libitum
[2] Live Weight Basis

The results from the budget analysis make sense intuitively. For instance, market swine production costs were greater for energy-restricted gilts from both genetic lines because they produced a larger number of offspring. One peculiar result which was seemingly contradictory was the greater profit and higher breakeven selling price in the L45X genetic line. One would assume the group with the lower breakeven selling price of progeny would also correspond to a greater profit or a lower loss. However, because restricted gilts produced a greater number of progeny, the magnitude of the profit/loss generated by the restricted gilt is greater than that of the ad libitum. To reiterate what was said previously, when profits are large for an average ad libitum gilt, they are greater for an average restricted gilt and when losses are large for an ad libitum gilt, they also are larger for a restricted gilt because of the increased reproductive production.

This section reported and discussed results from the enterprise budget analysis. The following section describes and analyzes the results from the stochastic simulation experiment.

4.2 Simulation Results

Cumulative distribution functions (CDFs) are one way the distribution of a data set can be visualized. Each point on the graph is the probability the data point will be at that corresponding level of measurement or less. For example, if the profit/loss curve of a gilt development program intersects the point ($100, 0.5), that program will have a 50% probability of generating up to a $100 profit. When analyzing continuous data, the lines on a CDF normally follow an S-shaped distribution. CDFs were used to compare systems by genetic line and are included as Figures 4.1-4.4 below. Figure 4.1 compares the breakeven selling price of LWxLR progeny between treatment groups, while Figure

4.2 displays profit/loss results of LWxLR gilts. Similarly, Figure 4.3 compares breakeven selling prices of L45X progeny between ad libitum and restricted treatment groups while Figure 4.4 illustrates profit/loss from ad libitum and energy-restricted L45X gilts.

In the simulation experiment involving LWxLR gilts, at all iterations in the simulation, restricted progeny had a lower breakeven selling price than ad libitum progeny (Figure 4.1). At the 0.5 cumulative probability level, the breakeven selling price of restricted and ad libitum LWxLR progeny were $41.27/cwt and $41.835/cwt, respectively. This means breakeven selling price of restricted LWxLR progeny had a 50% chance of being $41.27/cwt or less and ad libitum LWxLR progeny had a 50% chance of being $41.835/cwt or less. The range of breakeven differences between treatment groups went from a minimum of $0.42/cwt to a maximum of $0.93/cwt. Therefore, at all points, restricted LWxLR females produced market pigs at a lower per unit cost than ad libitum females. However, this did not mean restricted LWxLR females generated a greater profit at all points than ad libitum gilts. This concept is illustrated in Figure 4.2. The point at which the lines intersect (between the 0.048 and 0.067 cumulative probability levels) is the point where restricted LWxLR gilts become more profitable than ad libitum LWxLR gilts. To reiterate, approximately 6.3% of the time, ad libitum LWxLR females are more profitable than restricted LWxLR females. The other 93.7% of the time, restricted LWxLR gilts are more profitable than ad libitum LWxLR gilts. The differences in profitability range from ad libitum LWxLR gilts being $73.26 per gilt more profitable than restricted LWxLR gilts to restricted LWxLR gilts having a $224.08 advantage in profitability over their ad libitum counterparts.

The point where each line intersects the y-axis on Figures 4.2 and 4.4 is the point where gilts from each treatment group become profitable. For restricted LWxLR gilts, this occurs at approximately the 0.1907 cumulative probability level, while the zero profitability point of ad libitum gilts occurs at approximately the 0.2077 cumulative probability level. This indicates there is a 19.07% chance restricted LWxLR gilts will earn negative or zero returns, while ad libitum LWxLR females have a 20.77% chance of earning negative or zero returns. Therefore, restricted LWxLR gilts have an 80.93% chance of earning positive profits while ad libitum gilts have a 79.23% chance of earning positive profits.

It is important to note the reason why restricted LWxLR gilts have less profitability when market pig margins are largely negative. This is because although restricted LWxLR gilts are producing less expensive progeny on a per unit basis, these progeny are raised to market weight at a loss. Therefore, when margins are strongly negative, ad libitum females have a profitability advantage (of lower losses) because they are producing less progeny at a time when the cost of production is greater than the selling price.

Figure 4.1 Cumulative Distribution Function for LWxLR Gilts - Breakeven Selling Price of Progeny.

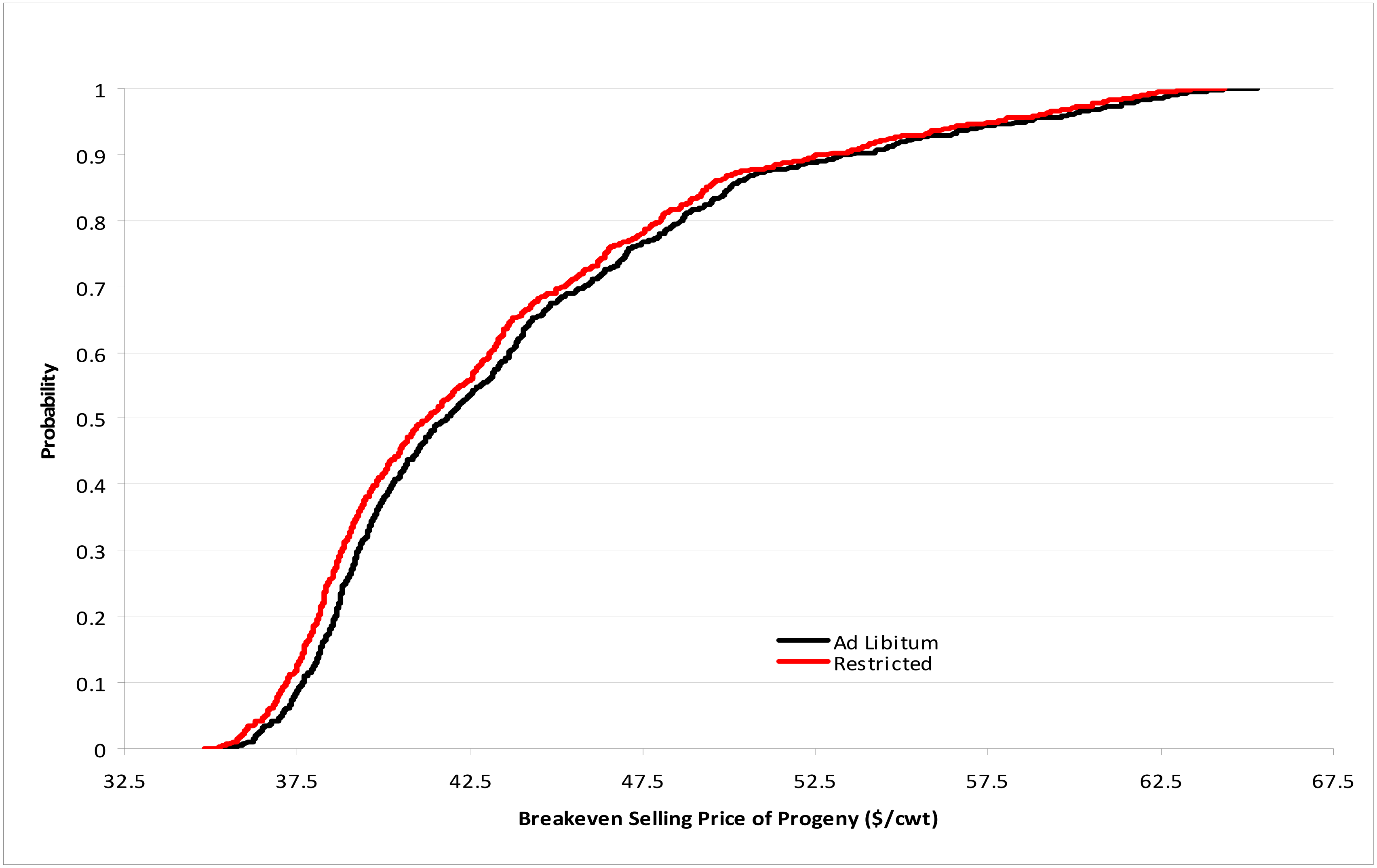
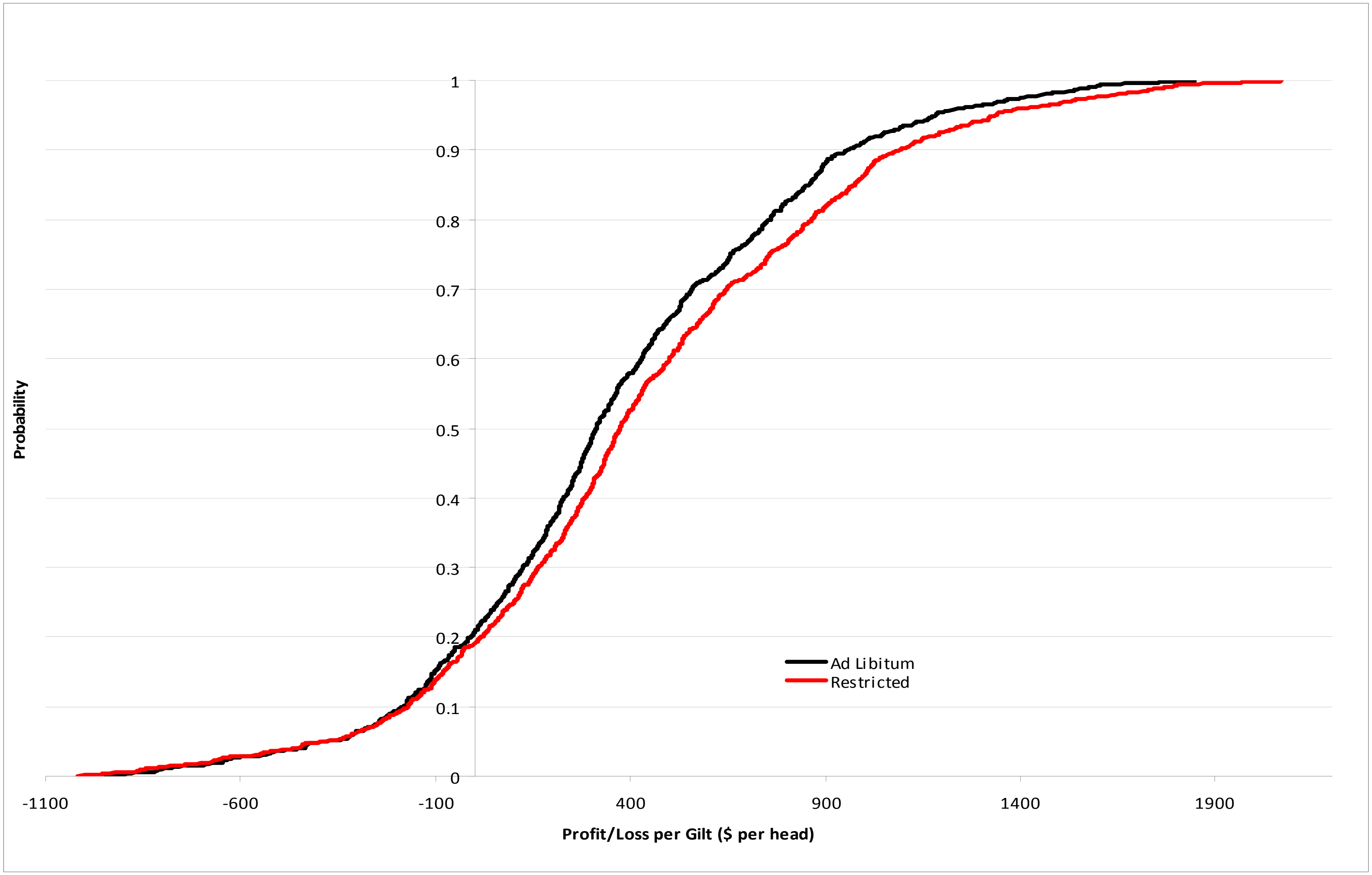


Figure 4.2 Cumulative Distribution Function for LWxLR Gilts – Profit/Loss per Gilt.



The results from the stochastic simulation experiment of L45X gilts are illustrated graphically in Figures 4.3 and 4.4. In Figure 4.3, the lines representing the breakeven selling prices of ad libitum and restricted L45X progeny are very similar. In fact, the lines are indistinguishable for much of the graph. This indicates the small variation in breakeven selling prices between ad libitum and restricted L45X progeny.

Figure 4.4 is similar to Figure 4.3 in that the two curves are very close to each other. This indicates the small variations in profitability between energy-restricted and ad libitum gilt development programs.

Figure 4.3 Cumulative Distribution Function for L45X Gilts - Breakeven Selling Price of Progeny.

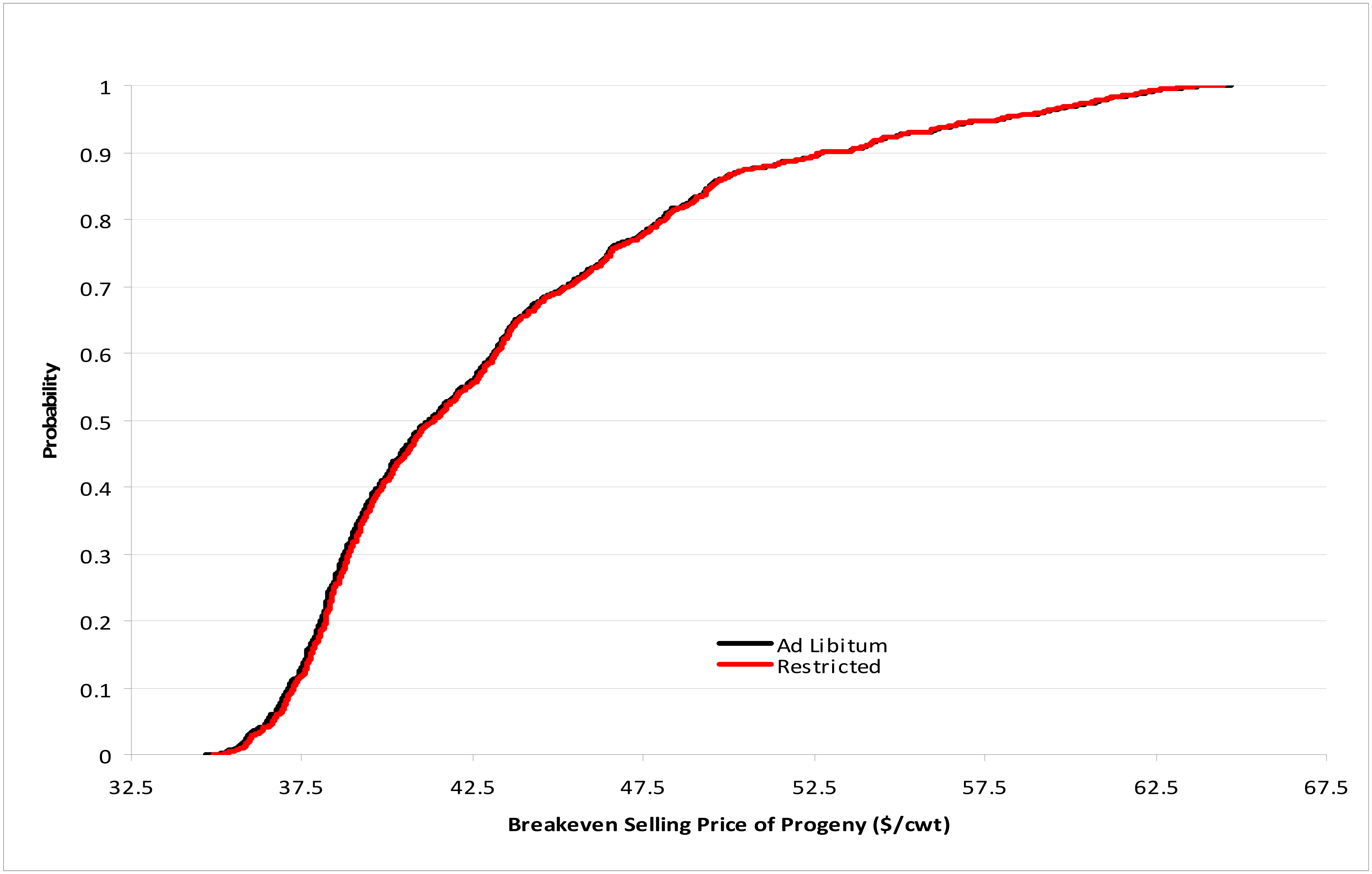
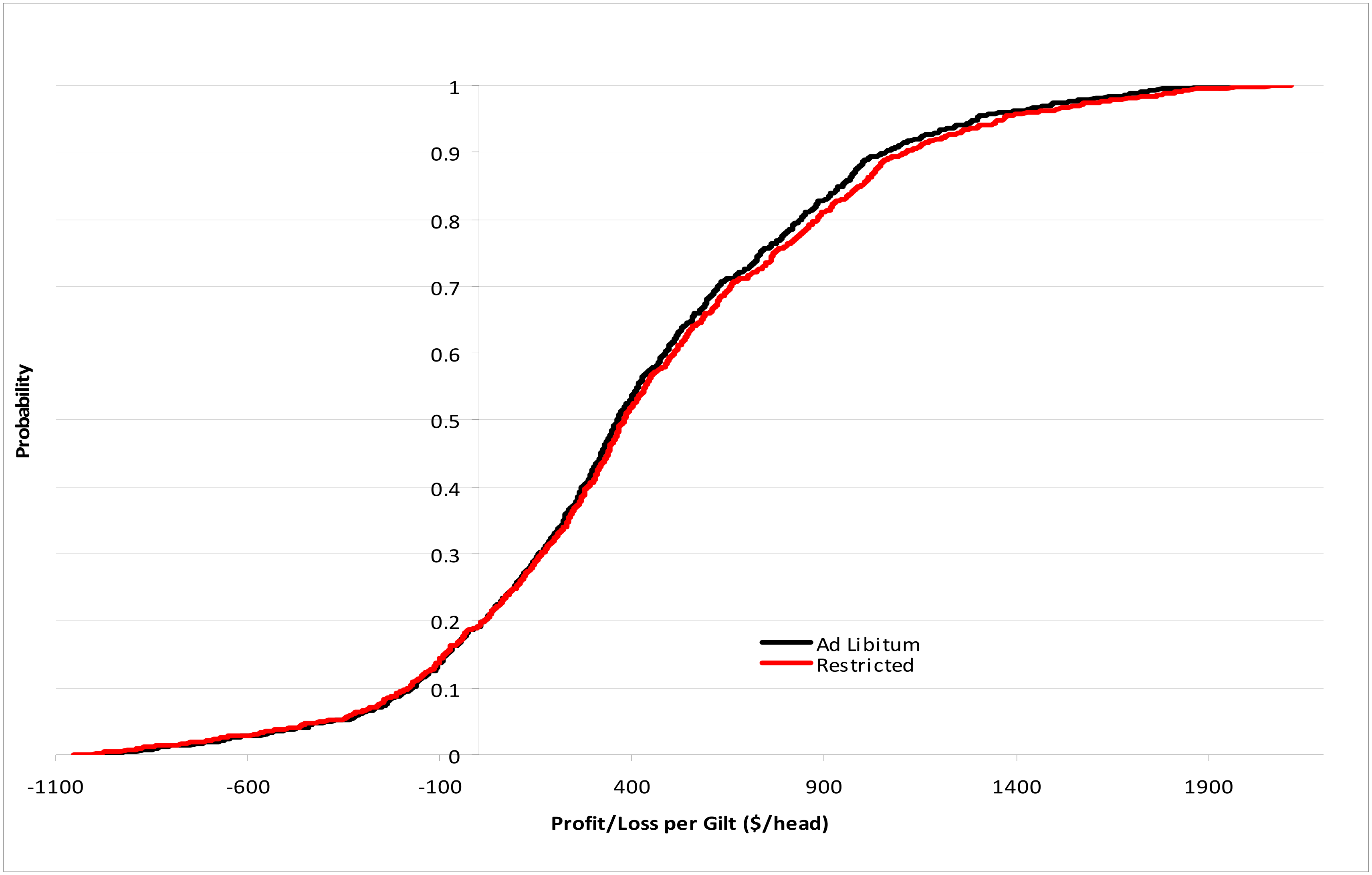


Figure 4.4 Cumulative Distribution Function for L45X Gilts - Profit/Loss per Gilt.



The results from the stochastic experiment between restricted and ad libitum L45X gilts were considerably different from the previous comparison between LWxLR gilts. First, restricted L45X gilts did not produce progeny at a lower breakeven selling price than ad libitum L45X gilts in all iterations. In fact, 89.7% of the time ad libitum L45X progeny had a lower breakeven selling price than their restricted counterparts, while 9.9% of the time restricted L45X progeny were less expensive to produce on a per unit basis than ad libitum L45X offspring (0.4% of time restricted and ad libitum L45X market pigs had the same breakeven selling price; Figure 4.3). Interestingly, the range of differences of breakeven selling prices went from ad libitum L45X progeny having a $0.23/cwt lower breakeven selling price to restricted L45X market pigs having a $0.23/cwt lower breakeven selling price (Figure 4.3).

At the 0.5 cumulative probability level, the breakeven selling price of restricted and ad libitum L45X progeny were $41.38/cwt and $41.26/cwt, respectively (Figure 4.3). This means breakeven selling price of restricted LWxLR progeny had a 50% chance of being $41.38/cwt or less and ad libitum LWxLR progeny had a 50% chance of being $41.26/cwt or less.

Even though ad libitum L45X market pigs were less expensive to produce on a per unit basis, this data did not translate to a greater profitability for ad libitum gilts. In fact, ad libitum L45X gilts had a greater profitability than their restricted counterparts 20.8% of the time, while restricted L45X gilts were more profitable in 79.2% of the iterations (Figure 4.4). The approximate range of cumulative probabilities where the more profitable gilt development system changed from ad libitum to energy-restricted was between 0.1722 and 0.2162 (Figure 4.4). The magnitude of the upper and lower bounds of the differences in profitability ranged from ad libitum gilts being $54.16 per gilt more profitable than restricted females to restricted females having a greater profitability of $104.78 per gilt (Figure 4.4).

At the 0.50 cumulative profitability level, restricted L45X gilts had a profitability of approximately $380.07 per gilt while ad libitum females had a profitability of $362.64 (Figure 4.4). This means there is a 50% probability of restricted L45X gilts having a profitability of $380.07 or less and a 50% chance of ad libitum L45X gilts earning a profitability of $362.64 or less.

The cumulative probability level where both energy-restricted and ad libitum L45X gilts earned $0 or negative returns was at approximately the 0.1917 level (Figure 4.4). This means there was approximately an 19.17% chance an L45X gilt would earn a zero or negative profit.

It is important to understand why the CDFs for L45X gilts are similar between treatment groups. This was caused by three main factors acting in unison to cancel each other out. For instance, the greater reproductive production and the lower cost of gilt development of restricted L45X gilts was offset by the greater value of sow cull credits. As previously mentioned, cull credits were greater because at early parities, ad libitum gilts were significantly heavier than restricted gilts, thus a greater quantity of meat was sold per culled sow. Hence, the results from L45X gilts were contradictory from an intuitive view.

Additionally, LWxLR progeny were less expensive to produce at all points and generated a greater profit the vast majority of the iterations of the simulation. This was caused by two of the same factors mentioned above: restricted gilts were less expensive to develop and produced a greater number of offspring. The difference in reproductive production between groups was larger in LWxLR gilts than in L45X gilts (4.93 more cwts per LWxLR gilt vs. 2.97 more cwts per L45X gilt; Table 4.2). Also, cull credits from sows were similar between LWxLR treatment groups on a per cwt basis. Thus, the positive economic factors of energy-restriction were not outweighed as was the case when analyzing results from L45X gilts.

Calculating the average differences between the curves on the profit/loss CDFs of each genetic line gives the expected additional returns to the energy-restricted gilt development system over the ad libitum development program. The average profit increase from energy-restriction for LWxLR and L45X gilts was calculated to be $67.26/gilt and $20.17/gilt, respectively. This number can be interpreted to be the additional expected profit per developed gilt generated by utilizing an energy-restricted gilt development program rather than an ad libitum development system. To reiterate, restricting energy intake during gilt development would lead to an increased in profit of $67.26 and $20.17 per LWxLR and L45X gilt, respectively.

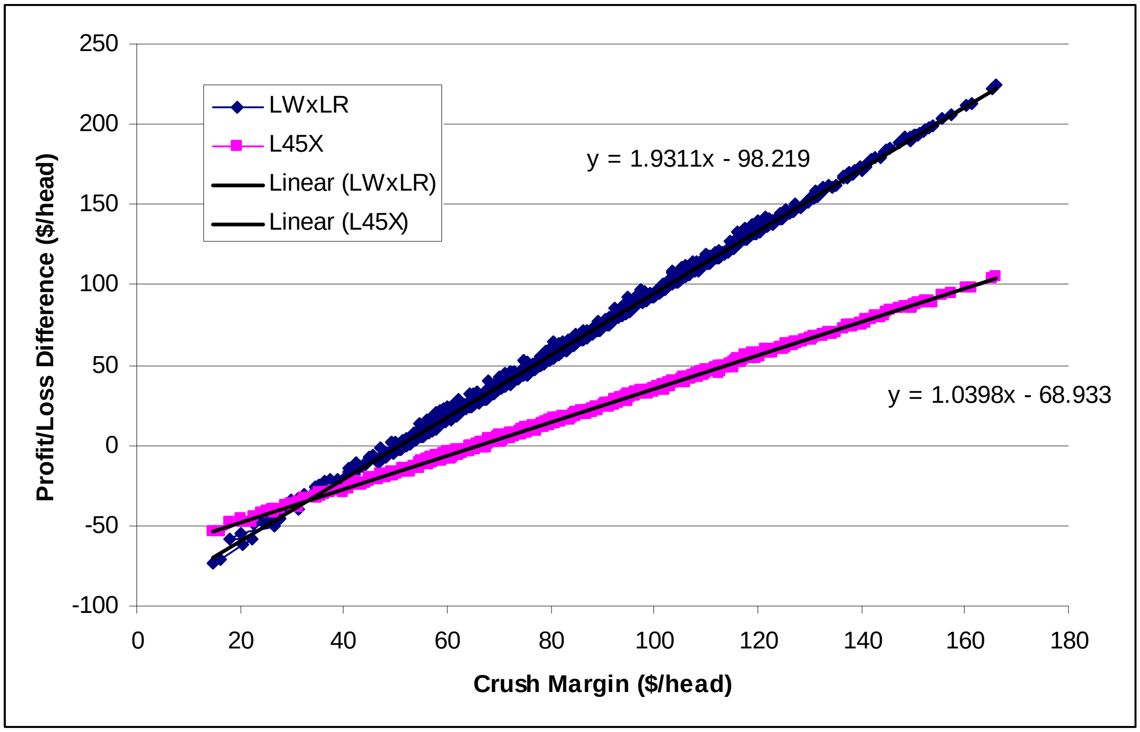
Another way to evaluate the results from the stochastic simulation is to compare the crush margin to the profit/loss difference between treatment groups. The crush margin as defined by Lawrence (2009) is given in the following equation:

$$CM = (MPSP_{SIM} \times MW) - (10 \times P_C + 0.075 \times P_{SBM}) \tag{4.1}$$

where CM = crush margin ($/head)
$MPSP_{SIM}$ = market pig selling price at each simulation iteration ($/cwt)
MW = market weight of pigs (cwts)
P_C = price of corn at each simulation iteration ($/bushel)
P_{SBM} = price of soybean meal at each simulation iteration ($/ton)

The crush margin roughly calculates the margin remaining from the sale of market pigs after the cost of the two largest feedstuffs has been deducted. Figure 4.5 illustrates the concept of crush margin as it relates to the difference in profit/loss between treatment groups.

Figure 4.5 Crush Margin vs. Profit/Loss Difference for LWxLR and L45X Gilts [1].



[1]Restricted minus Ad libitum

In both LWxLR and L45X gilts, as the crush margin increases so does the difference in profit/loss between treatment groups. In both cases, restricted progeny become more advantageous as the crush margin increases. For every $1 increase in crush margin, LWxLR and L45X restricted offspring generate approximately $1.93 and $1.04 of profit, respectively, while ad libitum progeny would have generated $1 of profit for every $1 increase in crush margin. The primary cause of this effect is the increased reproductive production of energy-restricted gilts of both genetic lines. However, because energy-restricted LWxLR progeny are also less expensive to produce than ad libitum LWxLR offspring per unit, the difference in profit between treatment groups is larger than that in L45X progeny.

It is important to understand the only parameters varied in the stochastic simulation were the prices of corn, soybean meal, market pigs, and culled sows. Thus, the R-squared values of the trend-lines on Figure 4.5 are essentially 1, showing little variation in results besides what was caused by variation in the input and output prices.

The point at which each line crossed the *x*-axis is where the energy-restricted gilt development system becomes more profitable than the ad libitum program. At this point, the crush margin reaches an approximate 'watch' point of \$51.50/head and \$66.00/head, restricted LWxLR and L45X gilts generate a greater profit their ad libitum counterparts, respectively. However, in both cases these points are approximate values and therefore, not critical points. Thus, a crush margin close to one of the decision points mentioned above would have ambiguous results. Therefore, making a production decision solely based on a crush margin that is close (within \$3/head) to a 'watch' point would not be advised.

Interestingly, the (*x*) coefficients of the trendlines in Figure 4.5 were greater than 1 and, in the case of LWxLR, the coefficient was much larger than 1. This indicates an energy-restricted gilt development program becomes more advantageous as the crush margin increased when developing LWxLR gilts. One would assume this is caused by the increased reproductive production in restricted gilts. This simulation experiment has shown restricted gilts are more profitable than ad libitum gilts. However, it would be incorrect to assume a producer could expect the same results (restricted gilts would generate larger profits at higher crush margins) in every genetic line of pigs because results from the two genetic lines evaluated in the simulation differed so largely.

4.3 Summary of Results

The results from the enterprise budget showed a greater profitability of energy-restricted gilts in both genetic lines by an average of $79.39 per LWxLR female ($513.28 per ad libitum gilt vs. $592.66 per restricted female; Table 4.2) and $27.27 per L45X gilt ($577.75 per ad libitum female vs. $605.02 per restricted gilt; Table 4.2). This was caused by the increased reproductive production of energy-restricted females as they produced an average of 4.93 more cwts per developed LWxLR gilt (46.33 cwts sold per ad libitum gilt vs. 51.26 cwts sold per restricted gilt; Table 4.2) and 2.97 more cwts per developed L45X gilt (49.75 cwts sold per ad libitum gilt vs. 52.72 cwts sold per restricted gilt; Table 4.2). However, while restricted LWxLR gilts had a $0.48/cwt lower breakeven selling price of progeny ($38.60/cwt ad libitum vs. $38.12/cwt restricted; Table 4.2) ad libitum L45X progeny had a $0.14/cwt lower breakeven selling price than restricted progeny ($38.07/cwt ad libitum vs. $38.21/cwt restricted; Table 4.2).

In the stochastic simulation experiment, ad libitum LWxLR progeny had a greater probability of earning a profit than ad libitum offspring approximately 6.3% of the time. The other 93.7% of the time, restricted LWxLR gilts are more profitable than ad libitum LWxLR gilts. Similarly, ad libitum L45X gilts had a greater profitability than their restricted counterparts 20.8% of the time, while restricted L45X gilts were more profitably 79.2% of the iterations.

When comparing breakeven selling price of progeny, at all points energy-restricted LWxLR offspring were less expensive to produce than ad libitum progeny on a per unit basis. Almost ninety percent of the time ad libitum L45X progeny had a lower breakeven selling price than their restricted counterparts, while 9.9% of the time restricted L45X progeny were less expensive to produce than ad libitum L45X offspring.

Chapter 5: CONCLUSION

This chapter summarizes the research presented and discussed in the four previous chapters. Additionally, this chapter will conclude with a discussion of the implications from the research presented in this paper and areas where further research would be useful.

5.1 Summary

In the budget analysis regarding LWxLR gilts, progeny from energy-restricted females were less expensive to produce on a per unit basis and generated greater profits. Offspring from L45X gilts generated a greater amount of profits, but also had larger per unit breakeven selling prices. Less expensive gilt development costs and greater reproductive production in both genetic lines would be expected to result in progeny from both lines being less expensive to produce on a per unit basis. This was not the case in L45X pigs because ad libitum L45X gilts were culled at a higher rate after first parity. Also, ad libitum gilts were heavier than restricted gilts. Thus, a greater quantity of cwts was sold per culled ad libitum female. Energy-restricted gilts were less expensive to produce, regardless of genetic line. These results have important implications for swine producers as restricting energy intake for breeding gilt production did not adversely affect sow productivity. The savings of feed costs counteracted the negative aspects of energy restriction in gilt development (increased rate of culling during development, etc.). Additionally, producing breeding gilts approximately $7/head cheaper, which was the average difference in energy-restricted females, reduced progeny breakeven selling prices in this study by an average of approximately $0.19/cwt sold.

The stochastic simulation experiment showed energy-restricted gilts generated a greater amount of profit than ad libitum gilts a higher percentage of the time. LWxLR gilts generated a greater profitability than their ad libitum counterparts 93.7% of the time, while restricted L45X gilts had a greater profitability than their restricted counterparts 79.2% of the time. Progeny from energy-restricted LWxLR females were less expensive to produce on a per unit basis at all points of the simulation. However, restricted L45X offspring had a greater breakeven selling price of progeny 89.7% of the time, a seemingly contradictory result because, as mentioned above, restricted L45X progeny generated a greater profit in 79.2% of the iterations in the simulation. Although these results appear to intuitively contradict each other, analysis of the results showed the greater reproductive production of restricted gilts caused the larger profits. Energy-restricted offspring are earning less profit per unit than ad libitum progeny, but the greater amount of market pigs from restricted gilts caused the greater returns.

At times when the returns to market pig production were negative, the increased rate of reproductive production from energy-restricted gilts caused the returns to this development system to be more negative than the returns to an ad libitum gilt development program. Thus, when the economics of market pig production were negative, ad libitum gilts were economically advantageous.

5.2 Implications and Future Research

One limitation of the analysis performed during the course of the research involved an assumption made in the budget analysis and simulation experiment that input and output prices did not vary during the life of the sow. Thus, the purchase prices of corn and soybean meal, and the selling prices of market swine and culled animals were the same throughout gilt development and during market pig production for all four parities. This assumption implicitly assumed the producer would have received a constant price for all purchases and in the sale of all products. The assumption was not based on real-world occurrences. However, any fluctuations in prices would have biased the model. Therefore, holding prices constant throughout the sow's lifetime was the practical solution and commodity price changes during the sow's life were ignored.

During the course of this research, there were several occurrences where discoveries were made that merit further discussion. One important caveat to this research was an increased rate of culled animals during the development stage when restricting energy in developing gilts. Thus, a greater number of gilts at the beginning of the program would be needed, leading to larger fixed costs incurred per developed gilt. As previously mentioned, this increase in fixed costs is more than offset by the decrease in feed costs when restricting energy, but could have practical implications for swine producers as more barn space would be needed to produce the same number of breeding gilts as the traditional method of gilt development.

Another important caveat to this research was the researchers (Johnson and Miller, 2005; Johnson et al., 2007) limit-fed energy-restricted gilts on the floor to regulate feed intake of each animal. Thus, the facilities used during gilt development were solid-floored. If this method of gilt development were replicated by a producer, they would need the capability of regulating feed intake of each animal. If breeding gilts were developed in large pens (a common industry method), limit-feeding may not be possible if dominant animals in each pen consumed a disproportionately large amount of feed, thus shorting the nutritional requirements of non-dominant gilts. Therefore, if an energy-restricted gilt development system is utilized, smaller pens of gilts would be needed with a feed delivery system capable of providing a specific, equal amount of feed to all gilts in the pen. Additionally, this method of gilt development would probably require a greater amount of management to insure gilts are consuming the proper amount of feed. When feed intake is self-regulated by gilts, this concern does not exist.

In both the enterprise budget analysis and during the simulation experiment, a 0% death loss was assumed from Johnson and Miller (2005) and Johnson et al. (2007) data for LWxLR progeny in the period after litters were weaned and until pigs were marketed. Although this result would be difficult to replicate in further research, it is justified because it was observed in the Johnson and Miller (2005) and Johnson et al. (2007) studies. Additionally, assuming a non-zero death loss that is constant between treatment groups would probably affect each group in similar manners, therefore not changing differences between treatment groups. Thus, varying production parameters between treatment groups could enhance the results discussed in this research.

Another way the research presented in this paper could be expanded would be the use of additional genetic lines of pigs to show if the results of energy-restricted gilt development vary among different types of pigs. Although differences between production parameters were not statistically significant in most cases, results from the deterministic budget and stochastic simulation varied between the two genetic lines used in this analysis. Thus, additional results may vary by genetic line even if production parameters are statistically similar.

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