# Optimal Hog Slaughter Weights Under Alternative Pricing Systems

**M. A. Boland, P. V. Preckel, and A. P. Schinckel***

*Abstract*

Three hog genotypes are simulated to determine how producer profits, economically optimal slaughter weights, and carcass component weights change under three pricing models. Live weight pricing pays more for the fatter barrows whereas a three component (separate payments for fat, lean, and byproducts) and six component (separate payments for major primal cuts, other lean, fat, and byproducts) pricing system pay more for the leaner gilts. Implications for selection of genetic stock and pricing system are presented.

**Key Words - swine production management, hog pricing systems, hog marketing**

Crop farmers in most regions of the United States cannot grow crops in the winter months and must harvest when the crop is ready in the fall. Pork producers raising animals in confinement buildings are not constrained by seasonal weather, and thus, have completely flexible starting and ending production points. Consequently, in order to remain profitable, pork producers need to maintain full facilities, and the opportunity cost of facilities is an important determinant of economically optimal slaughter weights. As a result, it may be shown that producers market their hogs where marginal profit per unit of time is equal to average profit per unit of time (Dillon and Anderson). Equivalently, producers seek to maximize average profit per unit of time.

Previous research on the optimal slaughter weight of livestock has focused on feeding strategies. These strategies have examined the price of feed and live weight market prices (Crabtree), the length of the feeding period (Kennedy et al.), and decision rules for determining optimal rations and optimal slaughter weight (Heady, Sonka, and Dahm). Feed prices and the cost of replacing the animal has been shown to be important in determining optimal slaughter weight (Chavas, Kliebenstein, and Crenshaw).

Historically, pork producers have been paid using a live weight pricing system for hogs. Generally, the heavier the hog, the more revenue a producer received, although discounts were employed by packers to deduct for heavy hogs (which were often breeding stock) and light weight hogs. Consumer demand for leaner pork products has forced packers and producers to change their buying and selling strategies, respectively (Grisdale et al.). In response to this, packers and processors have attempted to provide leaner wholesale primal cuts.

As an alternative to vertical integration or contractual arrangements, carcass merit pricing

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systems have been proposed as a means to pay pork producers for investing in leaner genetics. Many packers have adopted pricing systems which pay producers based on carcass traits such as percent lean, backfat depth, loin eye depth, and overall carcass uniformity. These carcass merit programs include grid systems, grade and yield, and component systems. In Jekanowski's recent survey of the top 25 pork packers comprising 97 percent of U.S. slaughter, all but two had a value-based or carcass merit pricing system option available to producers as well as the traditional live weight pricing system. Nationwide, about 36 percent of all hogs are purchased on these systems. The goal of these systems is to encourage producers to deliver leaner hogs.

In recent years, there have been efforts to encourage the use of carcass evaluation technologies and to establish guidelines for packers to pay producers for producing lean pork (NPPC). Carcass evaluation technologies have been developed that have the potential to be linked to carcass merit pricing systems so that information is provided to producers about overall carcass composition and quality (Forrest et al.). This information feedback in the form of economic rewards is needed if pork producers are to change their feed, genetics, or slaughter weights to provide packers with leaner, more uniform hogs (Lorenz). One such carcass merit pricing system, based on the perceived quality attributes of the carcass, has been proposed as a way to encourage producers to market leaner hogs (Brorsen et al.). Packers using this particular pricing system would purchase hogs based on carcass components such as pounds of lean. While pounds of lean is not the only measure of quality of importance to packers, it is a measure that is understandable to producers, processors and wholesale buyers. Other quality measures such as color, marbling, and firmness-wetness are more difficult to accurately measure but are quite variable in North American packing plants (Cassens et al.).

The objective of this paper is to determine differences in optimal slaughter weights and pork producer profits per hog for barrows and gilts sold under alternative pricing systems based on live weight and carcass components. Initially, three different pricing systems are outlined. Then a brief review of animal growth theory is detailed. Next, the data, results and sensitivity analysis for a deterministic optimization problem using the different pricing systems are presented. The article concludes by considering the implications of this research for pork producer decision making. This research extends previous research in two ways. First, three genotypes which reflect significant genetic variation are analyzed to determine differences in carcass components by sex and genotype. Second, the economics of these sex and genotype differences are calculated using the traditional live weight pricing system and two different component pricing systems which pay producers based on carcass characteristics. The analysis shows that a component pricing system which pays producers for producing pounds of lean pork will result in more profits per hog for producers with leaner genetics than a live weight pricing system. In addition, it is shown that there are higher profits per hog for gilts relative to barrows for each genotype.

## Live Weight and Component Pricing Systems

The availability of data to analyze economic impacts of genetics on animal growth in a dynamic setting is limited (Chavas, Kliebenstein, and Crenshaw). A deterministic hog production problem in continuous time is used in this analysis. With a traditional live weight pricing system, producers can be represented by a static, multiple input (feed and other inputs), single output (slaughter hogs) profit maximization problem expressed as a function of time. Thus, the problem may be written as:

$$(1)\quad \max_{t} \frac{P_{live}G(t) - FX - \sum_{i} W_i C_i(t) - D[G(t)]}{t}$$

where $P_{live}$ is the price per pound of live weight, $G(t)$ is total live weight in pounds expressed as a function of time $t$, $FX$ is the fixed cost of the feeder pig, $W_i$ is the price of input $i$, $C_i(t)$ is the cumulative quantity of the $i$th variable input used expressed as a function of time, and $D[G(t)]$ is the packer discount. The packer discount in equation (1) is based on the hog's live weight and penalizes producers for under-weight and over-weight animals. Hogs outside the desired weight range are discounted heavily to ensure that packers receive relatively uniform carcasses. This also helps ensure that they receive wholesale primal cuts of a fairly uniform size and sufficient weight. In practice, a sort discount is also employed to discount breeding stock or injured animals. However, this analysis assumes no sort discounts.

One proposed carcass merit pricing system would pay producers for three components in the carcass (Brorsen et al. refer to this as a three component model). The three components are lean, fat, and byproducts. This model would correspond to packers selling the wholesale carcass. The amount of lean that the packer can measure accurately is measured and valued on a dissected basis. Dissected lean is the amount of lean remaining when all trim fat is removed. Dissected fat is all fat that is trimmed away from the wholesale primal cuts (henceforth, lean and fat will refer to dissected lean and dissected fat). Thus, seam fat is included as lean and is priced as lean accordingly. Hence, producers seek to maximize average profit per unit of time with revenues coming from lean, fat, and byproducts. A constant payment for total byproducts is used because the total weight of byproducts is relatively stable across all slaughter weights within the reasonable range. For producers selling on this type of carcass merit system, a static multiple input, multiple output maximization problem can be represented as follows:

$$(2)\quad \max_t \frac{\sum_j P_j X_j(t) + B - FX - \sum_i W_i C_i(t) - V[HC(t)]}{t}$$

$P_j$ is the prices for the $j$th component ($j$ = lean, fat), $X_j(t)$ are the respective quantities of the $j$th component, $B$ is the byproduct payment constant, and $V[HC(t)]$ is the packer discount as a function of $HC(t)$, the hot carcass weight which is a function of time. A carcass weight discount is used to discount hogs whose carcass weight is too low or too high.

Brorsen et al. also propose a six component pricing system which is based on the weights of individual wholesale primal cuts and fat in the carcass. This model has six components: ham lean, loin lean, other lean, external fat, trimmable fat, and a byproduct constant. This particular model would correspond to packers selling lean, boneless pork. Separating the lean into ham, loin, and other lean is done for several reasons. First, the ham and loin are the most valuable portions of the carcass to the packer. Hence, producers may wish to raise pigs that meet packer specifications for a certain weight ham or loin. Second, new electromagnetic scanning technologies can be used to accurately measure the lean in the ham and loin (Forrest et al.). Third, repartitioning agents including pST have been shown to increase the quantity of total lean in the ham and loin (Gu et al., 1991b). Fourth, external fat is sold by packers based upon its lard value while trimmable fat from the wholesale primal cuts is sold based upon the price of the cut. Thus, the six component model provides a more accurate representation of the carcass in terms of lean, boneless value.

Producers selling hogs to a packer using a six component pricing system seek to maximize average profit per unit of time with payments for the lean components, the external and trimmable fat, and byproduct constant. Trimmed fat and external fat are treated as total dissected fat in this analysis. For producers selling on this carcass merit system, a static multiple input, single output maximization problem can be represented as follows:

$$(3)\quad \max_t \frac{\sum_k P_k X_k(t) + B - FX - \sum_i W_i C_i(t) - V[HC(t)]}{t}$$

where $P_k$ and $X_k(t)$ are the respective price and quantity of the $k$th component ($k$ = loin lean, ham lean, other lean, fat).

## Animal Growth Theory

Several biological relationships are needed to estimate the economics of animal growth as a function of time. These equations approximate the carcass weight and component weights needed for the three models. Simulation and mathematical models have been developed that predict animal growth components in response to energy and protein inputs (Gu et al., 1991a; Moughan, Smith, and Pearson; Whittemore and Fawcett). There are several methods available to calculate the desired growth functions in these models. Growth is assumed to be continuous with continuous rates of change. An exponential curve is frequently used to model the growth of animals. In hogs, the growth functions for fat-free lean, fat, and live weight typically increase at an increasing rate from about

10 to 20 weeks of age and then decrease at an increasing rate until its mature weight is reached (Whittemore). Because lean is the most valuable component in the hog, the protein deposition curve is separated into two functions. The level of protein determines the level of lean in an animal. In this analysis, an exponential function is used to estimate the relationship between weight and feed intake, protein deposition, and live weight. A constant elasticity function, expressed in logarithmic form, is used to estimate the relationship of protein to live weight. (All of the following equations are from Parks and are individually estimated by sex and genotype). *F(t)* is cumulative feed intake per unit of time and is approximated by the following function:

$$(4)\quad F(t) = C\left[t - t^{*}\left(1 - \frac{D}{C}\right)\left(1 - e^{-t/t^{*}}\right)\right]$$

where $C$ is the optimal feed intake of the genotype at maturity, $t^*$ is the appetance factor (the time required for a pig to reach 63 percent of its feed intake at maturity), and $D$ is the initial feed intake of the feeder pig. *G[F(t)]* is live weight expressed as a function of feed intake and is approximated by the following function:

$$(5)\quad G[F(t)]) = g_0 + (A - g_0)\left(1 - e^{-BB\frac{F(t)}{A}}\right)$$

where $A$ is the hog's weight at maturity (maximum of live weight gain), $BB$ is feed efficiency expressed as live weight divided by cumulative feed consumed (excluding the hog's maintenance and nutritional requirements), and $g_0$ is the initial weight of the feeder pig. Protein deposition can be expressed as a function of live weight. This is approximated by the following logarithmic function (Parks, p. 250):

$$(6)\quad Pr[G(t)] = 10^{a}G(t)^{b}$$

where *Pr[G(t)]* is protein deposition expressed as a function of live weight. Using these relationships, the marginal rate of protein deposition with respect to time can be approximated by the following:

$$(7)\quad \frac{\partial Pr(t)}{\partial t} = \frac{\partial Pr[G(t)]}{\partial G(t)}\frac{\partial G[F(t)]}{\partial F(t)}\frac{\partial F(t)}{\partial t}.$$

This provides an estimate of the rate of protein deposition or lean growth rate of the pig. In economic terms, the product on the right-hand side of equation (7) is the marginal rate of protein deposition, or lean growth, with respect to live weight, the marginal rate of live weight gain with respect to feed, and the marginal rate of feed intake with respect to time which yields the marginal rate of protein deposition over time. A producer can determine the causes of protein deposition over time by analyzing feed efficiency, total feed intake, and the partitioning of gain into lean and fat gain. An improvement in feed efficiency caused by genetics, a new feeding system which improves feed intake by reducing wastage, or the use of growth agents such as pST or ractopamine to shift the partitioning of gain towards more lean and less fat weight gain results in an increase in protein deposition. Combining equations 4, 5, and 6 yields protein deposition as a function of time and the marginal rate of protein deposition with respect to time is:

$$(8)\quad \frac{\partial Pr(t)}{\partial t} = b10^{a}G(t)^{b-1}\left[BBe^{-BB\frac{F(t)}{A}}\left(1-\frac{g_0}{A}\right)\right]\left[C\left(1-e^{-t/t^{*}}\right)\right].$$

Dependent variables such as protein deposition, hot carcass weight, and carcass components can be approximated as a function of live weight. These variables were estimated using nonlinear least squares in the following model (Thompson et al.):

$$(9)\quad Y_l(t) = 10^{a}G(t)^{b}$$

where $a$ and $b$ are constants and $Y_l$ represents the $l$th variable being approximated ($l$ = total lean, ham lean, loin lean, other lean, total fat, and hot carcass weight). These constants and feed efficiency ($BB$), live weight at maturity ($A$), appetance ($t^*$), feed intake at maturity ($C$), and initial feed intake ($D$) are presented in tables 1 and 2 by genotype and sex.

**Table 1.** Component Function (Equation 9) Coefficients[a] for Approximating the Lean Growth, Live Weight, and Component Relationships for Three Genotypes of Barrows and Gilts

| | Genotype 1 | | Genotype 2 | | Genotype 3 | |
|---|---|---|---|---|---|---|
| Variable | Barrows | Gilts | Barrows | Gilts | Barrows | Gilts |
| Total lean, a | -0.510 | -0.665 | -0.491 | -0.386 | -0.405 | -0.469 |
| Total lean, b | 0.988 | 1.084 | 1.017 | 0.973 | 0.948 | 1.002 |
| Ham lean, a | -0.878 | -1.018 | -0.918 | -0.826 | -0.862 | -0.901 |
| Ham lean, b | 0.910 | 0.999 | 0.979 | 0.941 | 0.922 | 0.963 |
| Loin lean, a | -1.180 | -1.289 | -1.191 | -1.134 | -1.244 | -1.287 |
| Loin lean, b | 1.010 | 1.084 | 1.054 | 1.038 | 1.057 | 1.104 |
| Other lean, a | -0.932 | -1.136 | -0.855 | -0.715 | -0.680 | -0.768 |
| Other lean, b | 1.031 | 1.151 | 1.026 | 0.961 | 0.911 | 0.977 |
| Total fat, a | -1.425 | -1.250 | -1.383 | -1.483 | -1.715 | -1.525 |
| Total fat, b | 1.462 | 1.354 | 1.388 | 1.431 | 1.578 | 1.453 |
| Carcass weight, a | -0.315 | -0.312 | -0.285 | -0.239 | -0.341 | -0.302 |
| Carcass weight, b | 1.085 | 1.086 | 1.073 | 1.052 | 1.096 | 1.078 |

[a]All coefficients are significant at 0.001. Standard errors and t statistics are available upon request from the authors.

**Table 2.** Growth Relationship (Equations 4 and 5) Variables[a] for Approximating the Lean Growth, Live Weight, and Component Relationships for Three Genotypes of Barrows and Gilts

| | Genotype 1 | | Genotype 2 | | Genotype 3 | |
|---|---|---|---|---|---|---|
| | Barrows | Gilts | Barrows | Gilts | Barrows | Gilts |
| Food efficiency, BB | 0.47 | 0.49 | 0.59 | 0.56 | 0.54 | 0.59 |
| Mature live weight, lbs, A | 599.08 | 634.35 | 489.88 | 517.51 | 500.53 | 445.86 |
| Appetance, days, $t^*$ | 130.27 | 200.27 | 92.26 | 142.80 | 143.50 | 206.78 |
| Mature feed intake, lbs/day, C | 9.98 | 11.50 | 7.14 | 8.69 | 10.58 | 11.03 |
| Initial feed intake, lbs/day, D | 4.99 | 4.96 | 4.18 | 3.52 | 4.95 | 3.43 |
| Feeder pig weight, lbs, $g_o$ | 55.66 | 55.66 | 55.90 | 55.91 | 55.66 | 55.66 |

[a]Approximated using nonlinear least squares.

Source: Thompson et al.

## Data

The data used to develop the growth and feed intake functions are from the 1991 Purdue Cooperative Swine Lean Growth Trial. While seven genotypes were used in that study, only three genotypes (the other four were similar genotypes in terms of variation) comprising 96 barrows and 95 gilts are used in this analysis. Barrows for genotypes 1, 2, and 3 averaged 44, 53, and 47 percent standardized lean (10 percent fat), respectively.[1] Gilts for genotypes 1, 2, and 3 averaged 49, 54, and 53 percent standardized lean (10 percent fat), respectively. The number of barrows for genotypes 1, 2, and 3 were 37, 22, and 37 respectively. The number of gilts for genotypes 1, 2, and 3 were 36, 24, and 35, respectively. Variables used in this study included hot carcass weight, component quantities of dissected lean (including loin, ham, and other lean), fat standardized lean (10 percent fat), total fat, byproducts, measures of feed intake, feed efficiency, and lean efficiency. Table 3 presents the means and standard deviations of relevant variables for the three genotypes.

In contrast to earlier studies of optimal slaughter weights, the data were separated by genotype and sex. Previous research has shown significant differences between genotypes and sex. In particular, gilts are leaner, have a lower backfat thickness than barrows, and have more lean in the primal cuts (Christian, Strock, and Carlson). Bereskin, Shelby, and Hazel showed that specific carcass traits are associated with genotypes.

Variable input use, $C_i(t)$, for all three models are for an all-in, all-out feeder pig finishing enterprise measured per pound of pork produced using the 1991 average of the 48 producers on the Iowa State University Swine Enterprise Record and corresponds to a producer who finishes 1,400 market hogs per year. The hogs were fed *ad lib* based on four rations (National Academy of Sciences). The first ration included 1.17 percent lysine and 19.3 percent protein, and was fed until the barrows and gilts reached 93 pounds (the cost of this ration was $0.0799 per lb). A second ration was used for gilts of 93 to 176 pounds. This ration included 1.06 percent lysine and 17.8 percent protein ($0.0712 per lb). Barrows, 93 to 176 pounds, and gilts, 176 to 255 pounds, were fed a ration that included 0.96 percent lysine and 16.5 percent protein ($0.0671 per lb). Finally, a ration that included 0.88 percent lysine and 15.2 percent protein were fed to barrows over 176 pounds and gilts over 255 pounds ($0.0641 per lb). Feed costs include corn, soybean meal, premix feeds, and other feed additives including lysine, protein, and fat. Production costs include utilities, fuel, electricity, telephone, veterinary medicine, depreciation, taxes, insurance, capital charges on fixed and operating capital, and hired labor, all measured per pound of pork produced respectively.[2] Production costs are assumed to sum to $0.0981 per pound of pork produced. Likewise, marketing and transportation charges were added.[3]

Feeder pig prices would be expected to vary according to the genetics in each of the three genotypes. However, such price data were not available. The average price per pound for these producers was $1.0406 which was multiplied by the initial weight of the purchased feeder pig. A fixed charge of $3.99, which includes transportation and veterinary costs, was added. Thus, the total cost function is the sum of feed costs based on daily feed intake; operating, veterinary medicine, and facility cost per day; and the initial feeder pig price.

All prices in this study are 1991 values. The live weight hog price used is the reported average plant bid price of $0.5003 per pound. The price for lean and fat is $1.15 and $0.25 per pound, respectively, with a constant total byproduct value of $11.32. The prices for trimmed ham, trimmed loin, and other lean used in the six component model are $1.25, $2.09, and $0.57, all measured per dissected pound, respectively (Whipker and Akridge). These component prices are obtained from the *National Provisioner Daily Market News Service* Yellow Sheet Prices and are adjusted to include transportation differentials and to reflect the products being sold on the wholesale market. The live weight and the component system prices have been adjusted to reflect the packer bid price at the plant; thus comparisons can be made between all three pricing systems. A return to management and non-hired labor per hog is calculated by multiplying the number of days until the optimal slaughter weight is reached by the average daily profit. As a

Table 3. Means and Standard Deviations by Genotype and Sex for Selected Variables at 250 Pounds

| | Genotype 1 | | | |
|---|---|---|---|---|
| | Barrows | | Gilts | |
| Variable | Mean | Std | Mean | Std |
| Hot carcass weight, lbs | 183.23 | 5.71 | 187.90 | 3.32 |
| Ham lean, lbs | 24.59 | 2.13 | 29.37 | 1.05 |
| Loin lean, lbs | 21.97 | 1.86 | 24.71 | 0.95 |
| Total lean, lbs | 69.39 | 3.61 | 79.44 | 2.11 |
| Total fat, lbs | 75.44 | 2.64 | 67.94 | 1.91 |
| Backfat, last rib, cm | 3.41 | 0.12 | 3.32 | 0.35 |
| Loin eye area, last rib, cm | 20.30 | 2.38 | 27.38 | 1.53 |
| | Genotype 2 | | | |
| Hot carcass weight, lbs | 184.07 | 2.72 | 185.68 | 2.97 |
| Ham lean, lbs | 34.06 | 0.72 | 34.10 | 0.70 |
| Loin lean, lbs | 25.63 | 1.08 | 30.34 | 1.69 |
| Total lean, lbs | 86.99 | 1.82 | 94.11 | 1.78 |
| Total fat, lbs | 64.66 | 2.57 | 61.75 | 0.46 |
| Backfat, last rib, cm | 2.78 | 0.26 | 2.18 | 0.18 |
| Loin eye area, last rib, cm | 28.30 | 1.91 | 30.30 | 0.91 |
| | Genotype 3 | | | |
| Hot carcass weight, lbs | 177.87 | 5.32 | 179.98 | 3.31 |
| Ham lean, lbs | 29.88 | 2.38 | 31.86 | 0.81 |
| Loin lean, lbs | 24.93 | 2.09 | 25.83 | 0.54 |
| Total lean, lbs | 78.65 | 4.05 | 88.84 | 2.36 |
| Total fat, lbs | 71.68 | 4.29 | 61.53 | 3.84 |
| Backfat, last rib, cm | 2.88 | 0.33 | 2.50 | 0.40 |
| Loin eye area, last rib, cm | 26.90 | 1.28 | 28.26 | 2.48 |

result, maximizing average daily profit represents maximum returns to management and labor per hog taking into account the opportunity cost of facilities.

The live weight, *D[G(t)]*, and carcass weight, *V[HC(t)]*, discounts are taken from an eastern Corn Belt pork packer and are typical of discounts in this area. Discounts are applied for hogs under 220 or over 275 pounds on a live weight pricing system. Those producers selling on this packer's carcass merit program are given discounts for carcass weights under 175 or over 205 pounds.[4] Because a step discount schedule substantially complicates the analysis, a quadratic function is fitted to the discount step function for live weight and hot carcass weight. This function is estimated using the following curve fitting problems:

$$(10)\quad \underset{\alpha_0,\beta_0,\delta_0}{minimize} \int \left(D[G(t)] - \alpha_0 - \beta_0 G(t) - \delta_0 [G(t)]^2\right)^2 dG$$

$$(11)\quad \underset{\alpha_1,\beta_1,\delta_1}{minimize} \int \left(V[HC(t)] - \alpha_1 - \beta_1 HC(t) - \delta_1 [HC(t)]^2\right)^2 dHC$$

where $\alpha_n$ (n=1, 2) is the intercept, $\beta_n$ is the coefficient for the first degree term, $\delta_n$ is the coefficient for the second degree term, and *D[G(t)]* and *V[HC(t)]* are the actual packer live weight and carcass weight, respectively. The fitted equation for the live weight and carcass weight discounts were:

$$(12)\quad D[G(t)] = 1.8205743 - .014747782G(t) + .00002979G(t)^2$$

$$(13)\quad V[HC(t)] = 1.54329149 - .01627893HC(t) + .00004284HC(t)^2$$

Because the three component and six component models are expressed in terms of a price for lean, the carcass weight discount was modified to determine the total carcass discount. The live price was expressed in terms of a carcass price by dividing live weight by the carcass weight and multiplying by the live weight price. The total amount of the actual discount expressed in terms of carcass weight is:

$$(14)\quad W[HC(t)] = HC(t)\left(\frac{G(t)(P_{live} - D[G(t)])}{HC(t)}\right)$$

where *W[HC(t)]* is the total value of the hot carcass weight discount. Tables 4 and 5 present the weights, and actual and approximated discounts for live weight and hot carcass weight.

The optimal slaughter weight is measured at the farm level. However, the live weight and component prices represent packer bids at the plant. Thus, marketing weight is multiplied by 0.96 to account for four percent shrinkage between marketing and slaughter. A mathematical programming model, formulated in GAMS 2.05, determined these optimal values using the MINOS 5.2 solver.

## Results

The results for all three genotypes by sex are presented in tables 6 through 11. A key difference is in optimal slaughter weights. Genotype 1 has the heaviest optimal slaughter weights for all three pricing systems. Genotype 3 has the lightest optimal slaughter weight for the live weight pricing system. On the other hand, genotype 2, whose barrows and gilts were leaner than the others, has the lightest optimal slaughter weight for the three component and six component pricing system. The optimal slaughter weights under all three pricing systems for all three genotypes are almost identical. The range of optimal slaughter weight differences between the pricing system was lowest for genotype 2 gilts and highest for genotype 3 barrows. The optimal slaughter weights under the live weight pricing system compare favorably with the 48 producer average of 252 pounds.

Net returns to management and labor under all three pricing systems vary widely. Per hog returns under the live weight pricing system range from \$12.85 (genotype 1 barrows) to \$16.12 (genotype 2 gilts). This is reasonably close to the 48 producer average profit per hog which was \$17.40 on a live weight pricing system. On the other hand, the range of net returns under the three component pricing system are \$8.92 (genotype 1 barrows) to \$29.36 (genotype 2 gilts). Similarly, the range of net returns on the six component pricing system is from \$5.28 (genotype 1 barrows) to \$27.02 (genotype 2 gilts). In addition, there are differences in the pricing systems between genotypes. The live weight pricing system gave the producer the lowest overall average net returns per hog except for genotype 1 and 3 barrows, which had the lowest percent lean relative to the others, for which it pays the most. The three component and six component systems pay the highest average profit for the lean genotype 2 barrows and gilts and genotype 3 gilts.

The six component pricing system pays producers on the weights of hams and loins. The hams and loins of genotype 2 barrows and gilts, and genotype 3 gilts are much larger than the other genotype sex combinations. For example, genotype 2 gilts have a lighter optimal slaughter weight than the genotype 1 gilts. However, the ham and loin lean weight is over four and two pounds more, respectively. Ham and loin weights on genotype 2 barrows are over five and three pounds more than genotype 1 barrows at similar weights, respectively. Furthermore, genotype 1 and 3 gilts have heavier hams and loins than their respective barrow counterparts. Genotype 2 gilt hams and loins are a pound heavier than the genotype 2 barrows. These differences in ham and loin lean weight are magnified when comparing the net returns per hog on the six component pricing system for the three genotypes.

**Table 4.** Weight, and Actual and Approximated Values for a Live Weight Discount Schedule of a Typical Eastern Corn Belt Pork Packer

| Live Weight (lb) | Actual Discount ($ per lb) | Approximated Discount ($ per lb) |
|---|---|---|
| 205 | -0.03 | -0.05 |
| 220 | 0.00 | -0.02 |
| 235 | 0.00 | 0.00 |
| 250 | 0.00 | 0.00 |
| 265 | 0.00 | 0.00 |
| 280 | -0.03 | -0.03 |
| 295 | -0.06 | -0.06 |

**Table 5.** Weight, and Actual and Approximated Values for a Hot Carcass Weight Discount Schedule for a Typical Eastern Corn Belt Pork Packer

| Carcass Weight (lb) | Actual Discount ($ per lb) | Approximated Discount ($ per lb) |
|---|---|---|
| 160 | -0.04 | -0.04 |
| 170 | -0.01 | -0.01 |
| 180 | 0.00 | 0.00 |
| 190 | 0.00 | 0.00 |
| 200 | 0.01 | -0.01 |
| 210 | -0.04 | -0.04 |

**Table 6.** Optimal Hog Slaughter Weight, Maximum Average Daily Profit, and Component Weights for Genotype 1 Barrows Under Three Pricing Models

| Variable | Live Weight | Three Component | Six Component |
|---|---|---|---|
| Weight, lbs. | 254.51 | 267.38 | 267.64 |
| Profit, $/day | 0.15 | 0.10 | 0.07 |
| Time, days | 94.50 | 101.23 | 101.37 |
| Carcass, lbs. | 184.50 | 194.65 | 194.85 |
| Lean, lbs | | 86.67 | |
| Percent lean | | 44.53 | 45.45 |
| Fat, lbs. | | 92.22 | 92.36 |
| Ham lean, lbs. | | | 24.48 |
| Loin lean, lbs. | | | 19.74 |
| Oth. lean, lbs. | | | 42.23 |

**Table 7.** Optimal Hog Slaughter Weight, Maximum Average Daily Profit, and Component Weights for Genotype 1 Gilts Under Three Pricing Models

| Variable | Live Weight | Three Component | Six Component |
|---|---|---|---|
| Weight, lbs. | 254.07 | 265.23 | 265.28 |
| Profit, $ | 0.16 | 0.19 | 0.15 |
| Time, days | 94.99 | 100.92 | 100.95 |
| Carcass, lbs. | 186.32 | 195.22 | 195.26 |
| Lean, lbs. | | 95.31 | |
| Percent lean | | 48.82 | 48.77 |
| Fat, lbs | | 81.29 | 81.31 |
| Ham lean, lbs. | | | 26.95 |
| Loin lean, lbs. | | | 21.69 |
| Oth. lean, lbs. | | | 46.49 |

**Table 8.** Optimal Hog Slaughter Weight, Maximum Average Daily Profit, and Component Weights for Genotype 2 Barrows Under Three Pricing Models

| Variable | Live Weight | Three Component | Six Component |
|---|---|---|---|
| Weight, lbs. | 252.44 | 260.42 | 260.98 |
| Profit, $ | 0.17 | 0.26 | 0.23 |
| Time, days | 99.66 | 104.65 | 105.01 |
| Carcass, lbs. | 185.12 | 191.41 | 191.84 |
| Lean, lbs. | | 101.31 | |
| Percent lean | | 52.96 | 52.91 |
| Fat, lbs. | | 68.67 | 68.87 |
| Ham lean, lbs. | | | 30.33 |
| Loin lean, lbs. | | | 23.14 |
| Oth. lean, lbs. | | | 47.98 |

**Table 9.** Optimal Hog Slaughter Weight, Maximum Average Daily Profit, and Component Weights for Genotype 2 Gilts Under Three Pricing Models

| Variable | Live Weight | Three Component | Six Component |
|---|---|---|---|
| Weight, lbs. | 253.54 | 259.29 | 260.04 |
| Profit, $ | 0.15 | 0.26 | 0.24 |
| Time, days | 112.75 | 116.46 | 116.96 |
| Carcass, lbs. | 187.16 | 191.63 | 192.21 |
| Lean, lbs. | | 104.15 | |
| Percent lean | | 54.15 | 53.95 |
| Fat, lbs. | | 66.55 | 66.83 |
| Ham lean, lbs. | | | 31.17 |
| Loin lean, lbs. | | | 24.36 |
| Oth. lean, lbs. | | | 48.39 |

**Table 10.** Optimal Hog Slaughter Weight, Maximum Average Daily Profit, and Component Weights for Genotype 3 Barrows Under Three Pricing Models

| Variable | Live Weight | Three Component | Six Component |
|---|---|---|---|
| Weight, lbs. | 250.63 | 265.69 | 266.70 |
| Profit, $ | 0.16 | 0.12 | 0.10 |
| Time, days | 98.21 | 104.89 | 105.62 |
| Carcass, lbs. | 182.85 | 191.94 | 192.73 |
| Lean, lbs. | | 90.56 | |
| Percent lean | | 47.14 | 46.94 |
| Fat, lbs. | | 81.70 | 82.19 |
| Ham lean, lbs. | | | 26.82 |
| Loin lean, lbs. | | | 21.26 |
| Oth. lean, lbs. | | | 42.28 |

**Table 11.** Optimal Hog Slaughter Weight, Maximum Average Daily Profit, and Component Weights for Genotype 3 Gilts Under Three Pricing Models

| Variable | Live Weight | Three Component | Six Component |
|---|---|---|---|
| Weight, lbs. | 250.67 | 261.84 | 262.81 |
| Profit, $ | 0.13 | 0.19 | 0.17 |
| Time, days | 108.69 | 116.05 | 116.70 |
| Carcass, lbs. | 180.91 | 189.61 | 190.36 |
| Lean, lbs. | | 99.76 | |
| Percent lean | | 52.66 | 52.45 |
| Fat, lbs. | | 68.06 | 68.42 |
| Ham lean, lbs. | | | 29.42 |
| Loin lean, lbs. | | | 23.74 |
| Oth. lean, lbs. | | | 46.71 |

Feed efficiency and lean efficiency for the three genotypes evaluated at the optimal slaughter weight are presented in table 12. Feed efficiency is defined as pounds of feed per pound of live weight gain. The range of feed efficiency is 2.65 (genotype 2 barrows) to 3.45 (genotype 1 barrows). Lean efficiency is defined as pounds of feed per pound of lean weight gain. The range on lean efficiency is 7.66 (genotype 2 gilts) to 12.1 (genotype 1 barrows). As expected, the leaner genotype had better feed and lean efficiency. The high ranking of the genotype 2 barrows and gilts on all three pricing systems was expected due to its production performance. The feed intake of genotype 2 barrows and gilts is just enough to maximize lean gain. This is evidenced by its having the highest net return per hog and lean gain performance.

These differences in feed and lean efficiency are magnified when reviewed in percentage terms. Genotype 2 barrows require approximately 21 percent less feed than the genotype 1 barrows to reach the same live weight. In addition, the genotype 2 barrows also require approximately 56 percent less feed to reach the same lean weight as genotype 1 barrows. Similar differences can be observed for the other genotypes. These differences also have implications for the composition of the lean. As indicated earlier, the

Table 12. Feed Efficiency[a] and Lean Efficiency[b] for Three Genotypes of Barrows and Gilts Evaluated at the Optimal Slaughter Weight

| | Feed Efficiency | Lean Efficiency |
|---|---|---|
| Genotype 1 barrows | 3.45 | 12.10 |
| Genotype 1 gilts | 3.38 | 10.07 |
| Genotype 2 barrows | 2.65 | 7.72 |
| Genotype 2 gilts | 2.80 | 7.66 |
| Genotype 3 barrows | 3.45 | 9.83 |
| Genotype 3 gilts | 2.90 | 8.14 |

[a]Defined as pounds of feed per pound of live weight gain.
[b]Defined as pounds of feed per pound of lean weight gain.

lean in the hams and loins is greater for the leaner genotype than for the relatively fatter genotype.

The live weight and carcass weight discount effectively allowed the packer to purchase a heavier hog with bigger primal cuts which are in some cases leaner (genotype 2 barrows and gilts, and genotype 3 gilts). This is the type of hog packers are demanding (Machan). Chavas, Kliebenstein, and Crenshaw noted that the maximum of the price premium function used was close to the optimal marketing weight of the hogs in their data.

The level of variability between genotypes and sex is evident from observing the means and standard deviations in table 3. In particular, genotype 1 and 3 barrows which are relatively less lean than the others, have a lower mean and a significantly higher variance for carcass weight and the component weights ($P<.01$). This suggests that packers buying these barrows will not have an accurate forecast of the amount of pork purchased. In addition, it suggests that a live weight pricing system will overpay for these barrows because a packer can purchase the genotype 2 barrows, and genotype 1, 2, and 3 gilts at the same price and obtain a heavier carcass weight.

The variability within genotypes is less than the variability over all genotypes. This observation implies that producers with the genetics analyzed here would desire to finish a single genotype rather than a group of mixed barrows and gilts from all three genotypes. Similarly, a single genotype with less variability, allows a producer to focus on managerial variables such as nutrition and helps reduce "tail enders" (hogs that do not mature as rapidly as other pigs and are not marketed with the group of hogs from their pen). In addition, packers would desire to purchase the single genotype because of the more uniform carcass and primal cut weights which allows easier product differentiation and reduces labor costs (Boland et al.). The effects of variability within groups based on genotype and sex were not reflected in the computer analysis.

A sensitivity analysis for the critical assumptions regarding prices was conducted on the results for the average genotype 3. The results are presented in table 13. Arc elasticities for live weight, marketing time, and profit per head, are calculated for a one percent change above and below the base value. The elasticities of optimal slaughter weight and marketing time with respect to feeder pig price, price of feed, live weight price per pound, price of lean per pound, price of ham lean per pound, and price of loin lean per pound, are relatively small. These elasticities indicate that increases in feed prices or output prices for any of the pricing models results in a decrease in optimal slaughter weight or time on feed.

The elasticities for the above input and output price variables with respect to average daily profit are all greater than one which implies a greater change in average daily profit is expected when input or output prices change. In addition, these elasticities with respect to profit are greater for gilts than barrows which implies that the leaner genotype 3 gilts are more sensitive than the

Table 13. Sensitivity of Optimal Slaughter Weight, Time, and Producer Profits to a One Percent Change in Selected Input Prices and Output Prices

| Barrows | Mean | 1% Change | Weight | Time | Profit |
|---|---|---|---|---|---|
| $P_{feeder}$ | 1.03 | 0.01 | 0.17 | 0.25 | -4.64 |
| $P_{feed}$ | 0.06 | 0.00 | 0.00 | 0.00 | -2.35 |
| $P_{live}$ | 0.52 | 0.01 | -0.12 | -0.17 | 8.59 |
| $P_{lean}$ | 1.15 | 0.01 | -0.10 | -0.12 | 5.03 |
| $P_{loin}$ | 2.09 | 0.03 | -0.03 | -0.05 | 3.10 |
| $P_{ham}$ | 1.25 | 0.01 | -0.03 | -0.05 | 2.42 |
| Gilts | | | | | |
| $P_{feeder}$ | 1.03 | 0.01 | 0.14 | 0.21 | -8.71 |
| $P_{feed}$ | 0.06 | 0.00 | 0.03 | 0.04 | -7.03 |
| $P_{live}$ | 0.52 | 0.01 | -0.12 | -0.18 | 12.79 |
| $P_{lean}$ | 1.15 | 0.01 | -0.23 | -0.13 | 7.39 |
| $P_{loin}$ | 2.09 | 0.03 | -0.05 | -0.06 | 4.59 |
| $P_{ham}$ | 1.25 | 0.01 | -0.04 | -0.06 | 3.46 |

genotype 3 barrows. These elasticities are much larger than those found by Chavas, Kliebenstein, and Crenshaw. This is due to a much smaller base for profit margins (about $48.00 per hog in their study and about $17.00 here) reflecting a different economic environment and the fact that this analysis, unlike that of Chavas, Kliebenstein, and Crenshaw, included fixed costs for facilities.

## Implications

The three component pricing system gives producers a higher net return to management and operator labor than the six component pricing system for the three genotypes in this data. While these hogs are not a random sample of the entire hog population, research on five other genotypes, in a different research trial with greater variability in feed and lean efficiency, has yielded similar results for hogs sold on typical packer carcass merit programs using backfat and electromagnetic scanning measurements (Boland, Schinckel, and Preckel).

However, if packers are able to differentiate the primal cuts and value lean, boneless pork, then the six component pricing system is the best estimate of the true value of the carcass (Brorsen et al.). The three component pricing system tends to overestimate the carcass value as evidenced by the higher net return over the six component pricing system for all three genotypes. This is due to the fact that the three component prices are weighted averages of the packers expected prices for end products. Thus, a packer selling primarily boneless, trimmed loins and boneless, cured hams will use a higher price for ham and loin whereas a packer selling wholesale trimmed carcasses will pay less for the loin and ham because these wholesale primal cuts still contain trimmable fat which is being sold at the wholesale primal cut price. The trimmable fat is being priced at the wholesale primal cut price. As expected, the live weight pricing system gives producers a higher net return to management and labor for the fat genotype 1 and 3 barrows. These differences confirm what many producers and packers have long suggested: a live weight pricing system overpays the fat hogs and underpays the lean hogs (Stahl).

A second implication is that if packers desire uniform hogs with more lean, they need to employ a carcass merit system that accurately estimates carcass value. In addition, packers need to use a pricing system that pays producers for producing lean in the ham and loin which accounts for approximately 85 percent of total carcass value. An added benefit to purchasing leaner hogs is the savings on labor and handling costs. Leaner carcasses have higher boning yields and require less trimming; hence, more lean is obtained for the same amount of labor (Boland et al.).

A third implication, for given genetics, is that the gilts are leaner than barrows and that lean efficiency is greater for gilts than barrows. The biggest difference is in genotypes 1 and 3 where the gilts have over ten pounds more lean than the barrows at similar weights. There is no discernible difference between gilts and barrows for genotype 2. This suggests that producers may find it advantageous to market genotype 1 and 3 barrows and gilts separately in order to optimize lean gain. In addition, the optimal number of days until slaughter for the barrows and gilts of the three genotypes are different which implies that producers who raise two or more of these genotypes should use separate facilities to make marketing easier. This also suggests that lean efficiency is higher in gilts than in barrows.

Producers with fat barrows should continue to market these hogs on a live weight pricing system. In addition, producers should feed these hogs to heavier weights to maximize average daily profits. On the other hand, producers raising genetically lean hogs should market their hogs to packers who value lean, boneless pork and who are using a pricing system that pays them for producing lean protein. Producers with these lean genetics should also market their hogs at lighter slaughter weights to maximize average profits. Continued progress towards providing consumers with leaner fresh and processed pork products means that packers will have to adopt more accurate measures to estimate lean and use them with carcass merit pricing systems to provide producers with more information about their hogs so that they can produce leaner pork. In addition, packers will have to provide more economic incentives to producers to ensure a steady supply of lean hogs with heavier, more uniform primal cut weights.

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## Endnotes

1. Recently, the National Pork Producers Council (NPPC) and the American Meat Institute (AMI) have asked producers, packers, and processors to report fat-free percent lean rather than alternative definitions such as percent standardized lean (5 or 10 percent fat). Zero percent fat-standardized lean is a definition that is uniform across packers, and hence represents a comparable measure of leanness for producers. However, because this study was completed prior to the recommendations of the NPPC Uniform Lean Information Committee, the percent standardized lean (10 percent fat) definition was used.

2. The producers in this sample were assumed to own their facilities rather than finishing hogs in rented facilities. These facilities are assumed to be newer, environmentally controlled buildings rather than modified open front barns, Cargill type units, or refurbished facilities (such as old dairy barns). The producer's profit function does not reflect those producers who finish hogs in commonly rented facilities such as those previously mentioned.

3. Packers typically pay transportation costs for hogs purchased from country buying stations while producers bear the transportation costs for hogs sold directly at the packing plant. For comparison purposes, we assume that all hogs are sold directly at the plant.

4. Without imposing these weight discounts, producers would desire to market hogs at unrealistically low weights because the rate of live weight and lean gain is tremendously high for very young animals such that average daily profit (assuming no discounts) is maximized by moving young animals through the system very quickly. However, packers desire mature hogs with heavier muscling and larger primal cut weights. Hence, discounts are used to ensure that producers can only profitably market hogs within a packers desired range. Using a moderately larger desired weight range would still yield the same results. However, using a smaller weight range would probably meet resistance from producers because of the difficulty in sorting and weighing hogs prior to marketing.