**Comparing Carcass End-Point and Profit Maximization Decision Rules**
**Using Dynamic Nonlinear Growth Functions**

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## 1.0 Introduction

Since the early 1990's, the beef cattle industry has become increasingly focused on carcass 'end-point' marketing strategies in an attempt to provide higher quality and more consistent meat products for consumers. This often used end-point strategy includes feeding to a target harvest weight. It has also been a long standing marketing strategy of the fed cattle industry to produce a consistent end-point product of 0.4 to 0.5 inches of back fat, primarily based on visual observation. While these strategies may ultimately result in higher quality and consistent beef for consumers at the aggregate level, they do not accomplish this on an individual animal basis. Further, this marketing method does not necessarily result in profit maximization. Targeting an end-point standard requires sufficient compensation to be profitable.

A classic profit maximization decision described in production economic text books is choosing the amount of input(s) where the value of the marginal product equals the marginal factor cost of production. However, in regard to a biological process, time and genetic variation are dimensions that complicate this decision rule and therefore are often ignored in general expositions of profit maximization for livestock producers. In livestock production, inputs are added at multiple points over time (typically daily), but revenues are realized only once. Beef cattle feeders experience two major production decisions in relation to a specific pen of cattle. The first is the choice of production process including input mixture. The second is the decision of when an animal(s) should be sold given market conditions and production efficiency.

To realize maximum profitability requires livestock producers to account for continuous and dynamic growth (i.e. weight and carcass characteristics) and its impacts on both cost and revenue. As far as the researchers are aware, no academic research has considered integrating dynamic non-linear growth functions into the profit objective function and thus constitutes our major contribution to the literature. This is surprising as there are numerous growth functions that are routinely estimated in the biological and scientific literature for numerous species of animals including cattle, pork, lambs and poultry.

The major finding of this paper is that a simple profit maximization strategy leads to higher average profits per head than the cattle industry's [target weight and/or 0.4 to 0.5 inches of back fat] end-point marketing strategy. Our results imply that the opportunity cost of this end-point marketing strategy is approximately $8.15 per head for the 1,657 cattle used in this analysis.

The presentation of this paper is as follows. First, relevant literature is summarized. Next, a general theory model is presented. Then, the data is described followed by the empirical model and methods being introduced. Lastly, the results are presented and conclusions and limitations of our current approach are discussed.

## 2.0 Literature

Given that no known literature exists where biological growth functions for cattle have been incorporated into a profit maximization analysis we first discuss the relevant literature pertaining to the general use of dynamic growth functions. Next a brief background of the relevant literature pertaining to the beef cattle feeding industry is summarized.

### *2.1 Growth Functions*

The use of dynamic nonlinear growth functions to predict the growth of living things is a well-documented practice in the biological and scientific literature. There are many applications for these types of growth functions in the animal and plant science areas. For instance, Strathe et al. (2010) utilize nonlinear growth functions to model pig growth while Khamis et al. (2005) use these functions to estimate Oil Palm yields.  Of particular interest to this paper is the use of these growth functions to estimate the growth of livestock, particularly cattle.

There has been much work analyzing cattle growth utilizing dynamic nonlinear growth functions.  Brown, Fitzhugh and Cartwright (1976) compare the effectiveness of five different growth functions when modeling weight-age relationships for cattle females.  They estimate the Logistc, Gompertz, Richards, and Brody growth functions and found the Brody function to be the best predictor of weight for their application.  Goonewardene, Berg and Hardin (1981) developed a similar approach using the Logistic, Richards, Brody, and Von Bertalanffy functions to analyze the growth of cattle females.  Forni et al. (2009) is another example where these growth functions are used to model the growth of Nelore cattle females.  Each of these studies analyze the growth of cattle over multiple years (life-cycle) of data as these females are tracked from birth through the time they are removed from the breeding herd.

There are many dynamic nonlinear growth functions to consider when estimating biological growth (Tsoularis, 2001).  Estimates of growth in animals are obtained by tracking live animal weight over time (age) and the functional form is often chosen by how well it fits the data and computational ease (Lopez et al., 2000; Brown, Fitzhugh and Cartwright, 1976). Growth functions can be fit individually or to a group of animals by estimating, among other things, biological parameters of the functions including the intrinsic rate of growth over time(i.e. Brown, Fitzhugh and Cartwright, 1976; Perotto, Coe and Lee, 1992; Menchaca et al., 1996). Further, growth and nutrient requirements are interrelated and feed sources necessarily impact growth rates (Perry and Fox, 1997; Pereda-Solis et al., 2011).

*2.2 Fed Cattle Industry*

While no research, to our knowledge, has focused on the incorporation of dynamic nonlinear growth functions into cattle profit functions, much research has focused on the profitability of the beef cattle feeding industry in general. Langemeier, Schroeder, and Mintert (1992) Lawrence, Wang, and Loy (1999) Mark, Schroeder and Jones (2000) among others identified factors that influence cattle feeding profitability and focused mainly on input and output prices. Cattle end weight is often noted in the literature as significantly impacting profitability. For instance, Feuz (1999) finds that weight explains 96% to 100% of the variation in revenue when cattle are sold on the cash market. Furthermore, Johnson and Ward (2005) find that weight explains 61% to %71 of the variation in revenue when cattle are sold under grid-pricing. Johnson and Ward (2005) also find in their study of grid-pricing signals that weight sends a stronger signal to producers than carcass quality characteristics.

## 3.0 Theoretical Model

Assuming the production technology has been chosen in advance, we represent the competitive producer's dynamic profit function throughout the production process as

$$\pi_i(t) = P_i(\mathbf{M}(t), \mathbf{H}_i(t)) \cdot Y_i(t; \mathbf{\Omega}_i) - C_i(\mathbf{w}(t)^T \mathbf{x}_i(t)) - K_i . \tag{1}$$

In equation (1), the $i^{th}$ animal's output price $P_i(\mathbf{M}(t), \mathbf{H}_i(t))$ is derived from a vector of market variables $\mathbf{M}(\mathrm{t})$ and a vector of hedonic value adjustments $\mathbf{H}_i(t)$. We assume market variables are independent of the producer's short run market timing decision and takes the buyer's hedonic value adjustments as given. Production costs are a vector of time dependent input prices and quantities denoted as $C_i(\mathbf{w}(t)^T \mathbf{x}_i(t))$, while $K_i$ is the summation of all other time independent costs.

Of particular interest for this analysis is the animal's weight $Y_i(t,\mathbf{\Omega}_i)$ at any moment during the production process. Weight is a function of time and a vector of biological parameters $\mathbf{\Omega}_i$ unique to each animal. The relative impact of these parameters determines the functional form of the underlying dynamic growth equation, often in nonlinear ways. Not explicitly represented in the model is that animal growth and hence the weight parameters $\mathbf{\Omega}_i$ are endogenously related to the vector of inputs $\mathbf{x}_i(t)$ ( Perry and Fox, 1997; Pereda-Solis et al., 2011). We ignore this complication throughout.

Generally, for a unique optimal market timing to exist, the time chosen must satisfy both the necessary

$$\frac{d\pi_i}{dt} = \underbrace{P_i'(\mathbf{M}(t),\mathbf{H}_i(t))\cdot Y_i(t;\mathbf{\Omega}_i) + P_i(\mathbf{M}(t),\mathbf{H}_\mathrm{i}(t))\cdot Y_i'(t;\mathbf{\Omega}_i)}_{\text{value of the marginal product}} - \underbrace{C_i'(\mathbf{w}(t)^T\mathbf{x}_\mathrm{i}(t))}_{\text{marginal factor cost}} = 0 \tag{2}$$

and sufficient conditions

$$\begin{aligned}\frac{d\pi_i^2}{d^2t} &= P_i''(\mathbf{M}(t),\mathbf{H}_\mathrm{i}(t))\cdot Y_i(t;\mathbf{\Omega}_i) + 2P_i'(\mathbf{M}(t),\mathbf{H}_\mathrm{i}(t))\cdot Y_i'(t;\mathbf{\Omega}_i) + P_i(\mathbf{M}(t),\mathbf{H}_\mathrm{i}(t))\cdot Y_i''(t;\mathbf{\Omega}_i) \\ &-C_i''(\mathbf{w}(t)^T\mathbf{x}_\mathrm{i}(t)) < 0\end{aligned} \tag{3}$$

of equation (1). Note for the sufficient condition to hold, the slope of the value of the marginal product, hence the producer's derived demand for time, need only be more negatively sloped than the marginal factor costs of production. Therefore, an optimal market time can be derived even if marginal factor costs decline over time. Due to the dynamics of output prices, input prices and input quantities, multiple locally optimal points may occur. However, only one point will satisfy both equations (2) and (3) globally.

## 4.0 Data Description

We use existing data from the Mississippi Farm to Feedlot Program which contain individual performance data for approximately 2,700 head of cattle. The Mississippi Farm to Feedlot Program was established in 1993 to evaluate feedlot and carcass performance for calves produced in Mississippi and to provide educational information to Mississippi beef cattle producers regarding retained ownership as a marketing alternative. It often serves as an introduction to cattle finishing and harvest production and marketing systems for these producers. The program is coordinated by the Mississippi State University Extension Service. Previously, researchers have used the information obtained via this program to evaluate the effects of steer age and morbidity on feedlot performance and carcass characteristics (Parish et al., 2012), the influence of the amount of time participants entered cattle into the program on feedlot performance and carcass traits (Parish et al., 2011). This program has also been used to evaluate the effectiveness of Extension programming (Parish and Smith, 2012; Parish and McKinley, 2005). However, the data have been used in the economic literature to analyze fed cattle marketing (Harri at al., 2009).

The data for this analysis were collected from 2005 to 2011 and include dates and animal weights recorded at four different points during the feeding process. Of the 2,700 head in the original data series, only 1,657 had all four weights recorded at the time 1) of delivery, 2) when moved out of the warm-up pen (on-test weight), 3) of re-implanting, and 4) of harvest. Visual back fat estimates for each animal were conducted by trained personnel to determine the harvest date. For only 592 head were animal birth dates recorded. Live weights ranged from 950 lbs. to 1600 lbs for the cattle with all four weights recorded. This and other descriptive statistics are shown in Table 1.

Also included in the data are all aggregated production costs. Production costs were calculated by summing the total cost of yardage, feeding and medication for each animal and dividing by the number of days each animal was on feed. The total feeding costs were estimated using the Cattle Value Discovery System (Perry and Fox, 1997). Finally, weekly fed cattle cash prices were obtained from the United States Department of Agriculture's (USDA) Agricultural Marketing Service (AMS) *Five Area Weekly Weighted Average Direct Slaughter Cattle* report (USDA, AMS, 2013a). A description of the price data is not provided because the data used differs for each animal depending on the dates each individual animal was on feed.

## 5.0 Growth Model, Estimation and Profit Simulation

In the first part of this section, we analyze the most common life-cycle growth equation used in both biological and economic sciences (Tsoularis, 2001), the logistic growth function, from which we estimate dynamic marginal physical product functions for each animal. Future endeavors should include a wider variety of life-cycle growth functions. However, as we will demonstrate in the first subsection, because feeders do not normally know the age of the animal they purchase, potentially cumbersome adjustments must be made to the life-cycle model for applicability in the cattle feeding industry.

Next, we describe the empirical methodology used to estimate the parameters of the weight function that is substituted into the profit model. To conclude this section, we describe a simplified version of the profit model depicted in equation (1) that we will use to determine the profit maximizing harvest dates. The intended results are to derive the opportunity cost of the carcass end-point marketing strategy to a profit maximization rule as depicted in equation (2).

*5.1 Growth Functions*

Estimation of the profit model depicted in equation (1) begins with the choice of a functional form(s) of the growth and corresponding weight function, $Y_i(t, \mathbf{\Omega}_i)$, followed by estimation of the parameters $\mathbf{\Omega}_i$. The life-cycle logistic growth function is

$$\frac{dY(t)}{dt} = kY(t)\left(M - Y(t)\right), \tag{4}$$

where $\frac{dY(t)}{dt}$ can be thought of as the instantaneous rate of weight gain at any point in time (age) with initial condition (birth weight) $Y(0) = \frac{M}{1+c}$ . $Y(t)$ are the observed weights across time (age) $t > 0$, $k > 0$ is an efficiency (growth constant) parameter, $c > 0$ is a phenotypic adjustment factor (genetic potential) parameter, and $M > Y(0)$ is the maturity weight parameter that is asymptotically approached as $t \to \infty$ similar to Brown, Fitzhugh and Cartwright (1976). Equation (4) states that the rate of growth is proportional to the weight in the current time period and to the difference between the current weight and the maturity weight. The corresponding sigmoidal weight function can be found by integrating the differential equation (4) resulting in

$$Y(t) = \frac{M}{1+ce^{-kMt}} \equiv Y_i(t, \mathbf{\Omega}_i) . \tag{5}$$

One limitation of the life-cycle growth functions in general is that the age of animal at time *t* must be known. Unfortunately, of the 1,657 useable data, only 592 of the cattle include birth date. To make better use of the data and account for the reality that cattle feeders rarely know the age of the animals they purchase, we modify equation (4) to

$$\frac{dY(t)}{dt} = k\left(M - Y(t)\right) \tag{6}$$

and set the initial condition $Y(0) = Y_0 > \frac{M}{1+c}$, where $Y_0$ is the delivery weight of an unknown aged animal. Because there is no observed minimum (birth) weight, equation (6) states that the rate of growth is proportional to the difference between the observed weight present and a fixed limit. This type of growth function is often referred to as a limited growth function. By integration the differential equation (6) results in what we call the days-on-feed (DOF) weight function,

$$Y(t) = e^{-kt}\left(Y_0 - M(1+e^{kt})\right) \quad . \tag{7}$$

This adjustment to the model does not require the econometrician to maintain a correspondence between age and time in the sense of marketing year, only the date and weight the animal entered the production process. Finally, note that this functional form does not result in a sigmoidal but rather a simple degenerative growth path as shown in Figure 1.

### *5.2 Empirical Estimation of the Weight Function*

Parameters for the days-on-feed logistic and the life-cycle logistic weight functions are estimated using the nonlinear least squares estimation procedure. This estimation procedure searches for the parameter values that minimize the residual sum of squares. The key assumptions of this procedure are that model errors are homoscedastic and uncorrelated with zero mean. An initial grid search is used to find adequate starting values of the parameters to be estimated. We use the Marquardt method (Marquardt, 1963) to guide the search for the parameters that lead to the minimized sum of squared errors (SSE). The different models estimated are measured and compared by how well they minimize the SSE.

*5.3 Profit Simulation*

We make two simplifications to the general model presented in equation (1) to maintain focus on the importance of growth function estimation for feeders. For simplicity we treat all output prices in the model as known, therefore $P_i'(\mathbf{M}(t), \mathbf{H}_{\mathrm{i}}(t)) \cdot Y_i(t; \mathbf{\Omega}_i) = 0$ and by extension $P_i''(\mathbf{M}(t), \mathbf{H}_{\mathrm{i}}(t)) \cdot Y_i(t; \mathbf{\Omega}_i) = 0$. This restricts the producer in making rather myopic daily marketing decisions as opposed to establishing price expectations. We further assume the producer has observed output price either publicly or privately and has purchased the required inputs in advance of production. Furthermore, given the cost data are provided only at the end of the feeding period, we restrict $C_i''(\mathbf{w}(t)^T \mathbf{x}(t)) = 0$ and hence treat marginal factor costs of production as constant equal to the average variable cost of production. We later demonstrate that neither simplification violates either the necessary nor sufficient conditions provided in equations (2) and (3).

Though the cattle in the data were sold on a carcass merit basis, the growth functions specified are for live weight and not for carcass characteristics. To test the robustness of our results, we compare three plausible cash output prices $p \in (\text{min, mean, max})$ observed during the marketing window. The marketing window we consider is from 950 lbs. to 1450 lbs. live. Assuming a 63 percent yield results in corresponding carcass weights of 600 lbs. to 900 lbs., the minimum and maximum live weight that will not result in price discounts applied to light and heavy weight carcasses (USDA, AMS, 2013b).

As a result of the simplifications the general form of the estimated profit equations simulated per animal are

$$\hat{\pi}_{ip}(t) = P_{ip} \cdot Y_i(t; \hat{\mathbf{\Omega}}_i) - t \cdot C_i(\mathbf{w}(h)^T \mathbf{x}_{\mathrm{i}}(h)) - K_i, \tag{8}$$

where $C_i(\mathbf{w}(h)^T\mathbf{x}_\mathrm{i}(h))$ is the animal's estimated average daily production costs calculated at the actual harvest date $t = h$. These costs include the daily yardage, feed and medicine charges. By substitution of the estimated parameters $\hat{\mathbf{\Omega}}_i$ into equations (5) and (7) and equations (5) and (7) into (8) result in the two simulated profit functions of the forms

$$\text{Life-cycle: } \hat{\pi}_{ip}(t) = \frac{P_{ip}\hat{M}_i}{1+\hat{c}_i e^{-\hat{k}_i\hat{M}_i t}} - C_i(\mathbf{w}(h)^T\mathbf{x}_\mathrm{i}(h)) - K_i \quad \text{and} \tag{9}$$

$$\text{Days-on-feed: } \hat{\pi}_{ip}(t) = e^{-\hat{k}_i t}\left(Y_{0i} - \hat{M}_i(1+e^{\hat{k}_i t})\right) - C_i(\mathbf{w}(h)^T\mathbf{x}_i(h)) - K_i\,. \tag{10}$$

The corresponding necessary condition for the Life-cycle model is

$$\frac{d\hat{\pi}_{ip}}{dt} = \underbrace{\frac{P_{ip}\hat{c}_i\hat{M}_i^2\hat{k}_i e^{\hat{k}_i\hat{M}_i t}}{\left(\hat{c}_i + e^{\hat{k}_i\hat{M}_i t}\right)^2}}_{\text{value of the marginal product}} - \underbrace{C_i}_{\text{marginal factor cost}} = 0\ . \tag{11}$$

Solving (11) for $t$ results in the optimal marketing at period

$$\hat{t}_{ip}^* = \ln\left(\frac{P_{ip}\hat{c}_i\hat{M}_i^2\hat{k}_i + C_i\left(-2\hat{c}_i + \sqrt{\frac{P_{ip}\hat{c}_i^2\hat{M}_i^2\hat{k}_i\left(P_{ip}\hat{M}_i^2\hat{k}_i - 4C_i\right)}{C_i^2}}\right)}{2C_i}\right)\frac{1}{\hat{k}_i\hat{M}_i}$$ , and more generally

satisfies the sufficient condition as $\dfrac{d^2\pi_{iP}}{dt^2} = -C_i^2\sqrt{\dfrac{P_{ip}c_i^2M_i^2k_i\left(P_{ip}M_i^2k_i - 4C_i\right)}{C_i^2}}\dfrac{1}{P_{ip}c_iM_i} < 0$ for all conventional positive output price, production cost and estimated growth parameters.

The corresponding estimated necessary condition for the Days-on-feed model is

$$\frac{d\hat{\pi}_{ip}}{dt} = \underbrace{P_{ip}e^{-\hat{k}_i t}\hat{k}_i(\hat{M}_i - \mathrm{Y}_{0i})}_{\text{value of the marginal product}} - \underbrace{C_i}_{\text{marginal factor cost}} = 0\ . \tag{12}$$

Solving (12) for $t$ results in the optimal marketing at period $\hat{t}_{ip}^{*} = \ln\left(\frac{(P_{ip}\hat{k}_i(\hat{M}_i - \mathrm{Y}_{0i})}{C_i}\right)\frac{1}{\hat{k}_i}$ , and

more generally satisfies the sufficient condition as $\frac{d^2\pi_i}{dt^2} = -C_i k_i < 0$ for all conventional positive

production cost and growth parameter $k_i$.

Finally, we compare the profit maximization approach we have outlined thus far to that of the constant end-point marketing strategy utilized by the feeding industry today. To do so we simply compare the differential $\hat{\pi}_{ip}(t_{ip}^{*}) - \hat{\pi}_{ip}(h_i)$.

## 6.0 Results

For model convergence purposes, we constrained the maturity weight parameter $M$ between 1,200 pounds and 1,800 pounds in both the life-cycle and days-on-feed models. This constraint was found to significantly affect the estimated parameters at conventional levels for only three percent and thirteen percent of the observations for the life-cycle and days-on-feed models, respectively.

Results in Table 2 report the profit and days on feed differences between the days-on-feed model and the end-point marketing strategy for only the 592 head with a reported birth date. Table 3 shows the profit and days on feed differences between the life-cycle logistic model and the end-point marketing strategy for the cattle with a reported birth date. We use Tables 2 and 3 to compare the days-on-feed and general life-cycle logistic models for those cattle for which a birth date was collected. While two of the mean profit differences are higher using the general life-cycle logistic model, it is important to note the increased standard deviation for each mean. We found that, on average, the general life-cycle logistic model overestimated the predicted weights and overall underperformed the modified logistic model. This is further evidenced by the average mean squared error (MSE) comparison presented in Table 4 between the two models.

Results in Table 5 report the profit and days on feed differences between the days-on-feed model and the end-point marketing strategy actually used for the cattle in the dataset. Results in Table 5 show a total profit improvement of $12,000 to $15,000 for the 1,657 cattle analyzed when using the profit maximizing approach to choose harvest time as opposed to the end-point marketing. For instance, if the expected price received was the average price for the feeding period, then the profit maximization approach using the days-on-feed model would have fared $7.26 per animal better than the end-point marketing strategy actually employed, on average. This difference is created by choosing the optimal harvest date which is shown to be, on average, 9.02 days sooner under the profit maximizing approach if the average price for the feeding period is expected. Not surprisingly, the price plays a large role in the optimal number of days on feed. However, it is interesting to note that for the cattle in the dataset used there was a profit improvement, on average, for the entire window of prices we considered. Table 6 shows the mean errors from the days-on-feed model between the estimated weights and known weights at each time the cattle were actually weighed. In particular, results in Table 6 show that the days-on-feed model underestimated the mean harvest weight by 20.96 lbs. which we consider acceptable based on the variation in fill and empty weights.

Table 7 presents the mean differences between the days-on-feed model and the end-point marketing strategy broken down into delivery weight groups. Of interest is the higher profit differences for the three heavier delivery weight groups as opposed to the lighter groups. This indicates that heavier cattle, when delivered, show the greatest area for potential profit improvement through using the profit maximization approach.

## 7.0 Conclusions

Although the results of this research is specific to fed cattle production, the methods used could be applied to other animal production processes. The methodology presented by this research facilitates discussion pertaining to 'end-point' marketing strategies. The results presented in this paper imply the importance of treating weight as a factor that increases revenue instead of simply a target. On balance, there is a cost associated with adding weight to livestock. The profit maximization methodology described in this paper presents a new way to consider livestock marketing decisions by accounting for the dynamic growth.

It is important to note the absence of dynamic prices and costs in this model. We found that the inclusion of daily cash prices led to the optimal harvest decision being made solely on price effects. While price is certainly a very important factor to consider when choosing when to harvest cattle, the purpose of this paper is to present a methodology on how to incorporate estimated growth into a profit maximization decision. Concerning dynamic marginal costs, we use a constant average variable cost per day for each animal to represent the additional cost associated with feeding one more day. We acknowledge that a fully specified profit maximization model for the livestock industry must include three dynamics: (1) growth, (2) prices, and (3) costs. Future work on this topic is needed to extend the model to include dynamic price and cost paths to more realistically capture the price effects in the cattle industry.

**Table 1. Descriptive Statistics**

| Description | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|
| *Delivery Weight* | 709.07 | 107.98 | 380.00 | 1116.00 |
| *On-Test Weight* | 834.86 | 123.86 | 440.00 | 1190.00 |
| *Re-Implant Weight* | 979.86 | 122.07 | 500.00 | 1548.00 |
| *Harvest Weight* | 1242.64 | 151.20 | 950.95 | 1599.97 |
| *Average Variable Cost* | 2.08 | 0.31 | 1.22 | 3.57 |

Note: N=1657

**Table 2. Estimated Profit and Days on Feed Differences for Known Birth Date Cattle: Days-On-Feed Logistic Model vs. End-Point Marketing Strategy.**

| Variable | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|
| $\pi$ Difference \| Min Price | 12.12 | 14.44 | 0.00 | 97.12 |
| $\pi$ Difference \| Avg Price | 8.46 | 13.03 | 0.00 | 88.35 |
| $\pi$ Difference \| Max Price | 8.38 | 13.24 | 0.00 | 82.32 |
| DOF Difference \| Min Price | -35.76 | 36.31 | -167.00 | 98.00 |
| DOF Difference \| Avg Price | -17.23 | 37.63 | -154.00 | 112.00 |
| DOF Difference \| Max Price | 2.85 | 40.51 | -142.00 | 121.00 |

Note: N=592

**Table 3. Estimated Profit and Days on Feed Differences for Known Birth Date Cattle: Life-Cycle Logistic Model vs. End-Point Marketing Strategy.**

| Variable | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|
| $\pi$ Difference \| Min Price | 16.50 | 17.27 | 0.00 | 180.38 |
| $\pi$ Difference \| Avg Price | 17.25 | 18.65 | 0.00 | 170.85 |
| $\pi$ Difference \| Max Price | 20.98 | 23.59 | 0.00 | 161.15 |
| DOF Difference \| Min Price | -6.26 | 54.97 | -167.00 | 135.00 |
| DOF Difference \| Avg Price | 7.88 | 55.84 | -167.00 | 170.00 |
| DOF Difference \| Max Price | 20.36 | 57.75 | -152.00 | 197.00 |

Note: N=592

**Table 4. Mean Squared Error Comparison for Known Birth Date Cattle: Days-on-feed Logistic Model vs. Life-cycle Logistic Model**

| Variable | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|
| Days-On-Feed Logistic | 1544.47 | 1906.11 | 0.00 | 13435.76 |
| Life-Cycle Logistic | 2146.42 | 2464.03 | 12.47 | 27758.43 |

Note: N=592

**Table 5. Estimated Profit and Days on Feed Mean Differences: Days-On-Feed Logistic Model vs. End-Point Marketing Strategy.**

| Variable | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|
| π Difference \| Min Price | 9.39 | 13.27 | 0.00 | 121.02 |
| π Difference \| Avg Price | 7.26 | 11.77 | 0.00 | 117.06 |
| π Difference \| Max Price | 7.33 | 11.82 | 0.00 | 111.72 |
| DOF Difference \| Min Price | -22.71 | 35.75 | -167.00 | 124.00 |
| DOF Difference \| Avg Price | -9.02 | 36.24 | -154.00 | 150.00 |
| DOF Difference \| Max Price | 4.92 | 38.23 | -142.00 | 180.00 |

Note: N=1657

**Table 6. Estimated Mean Weight Errors: Days-On-Feed Logistic Model**

| Variable | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|
| Test-Weight Error | 16.46 | 30.52 | -118.02 | 145.71 |
| Re-Implant Weight Error | 21.45 | 27.96 | -66.88 | 210.04 |
| Harvest Weight Error | -20.96 | 22.87 | -134.92 | 63.09 |

Note: N=1657

**Table 7. Estimated Profit and Days on Feed Mean Differences by Delivery Weight: Days-On-Feed Logistic Model vs. End-Point Marketing Strategy.**

| Variable | <500 | 500-600 | 600-700 | 700-800 | 800-900 | >900 |
|---|---|---|---|---|---|---|
| N | 40 | 222 | 499 | 562 | 273 | 61 |
| π Difference \| Min Price | 9.87 | 9.47 | 8.63 | 9.84 | 8.78 | 13.48 |
| | (11.24) | (9.68) | (10.93) | (15.23) | (13.18) | (21.41) |
| π Difference \| Avg Price | 8.26 | 5.91 | 6.61 | 7.90 | 7.27 | 10.90 |
| | (13.13) | (8.02) | (9.31) | (13.71) | (11.69) | (18.74) |
| π Difference \| Max Price | 10.18 | 6.32 | 7.65 | 7.27 | 6.78 | 9.62 |
| | (18.42) | (9.19) | (9.65) | (13.10) | (11.83) | (17.20) |
| DOF Difference \| Min Price | -17.20 | -31.97 | -20.64 | -21.73 | -19.74 | -31.92 |
| | (46.40) | (33.60) | (38.21) | (34.73) | (31.14) | (37.64) |
| DOF Difference \| Avg Price | 2.05 | -11.81 | -3.49 | -11.11 | -11.07 | -22.95 |
| | (51.76) | (36.44) | (38.10) | (34.43) | (31.62) | (36.56) |
| DOF Difference \| Max Price | 21.88 | 9.06 | 14.88 | 0.13 | -4.63 | -15.98 |
| | (58.34) | (41.25) | (39.62) | (34.42) | (30.86) | (35.64) |

Note: Standard deviations in parentheses

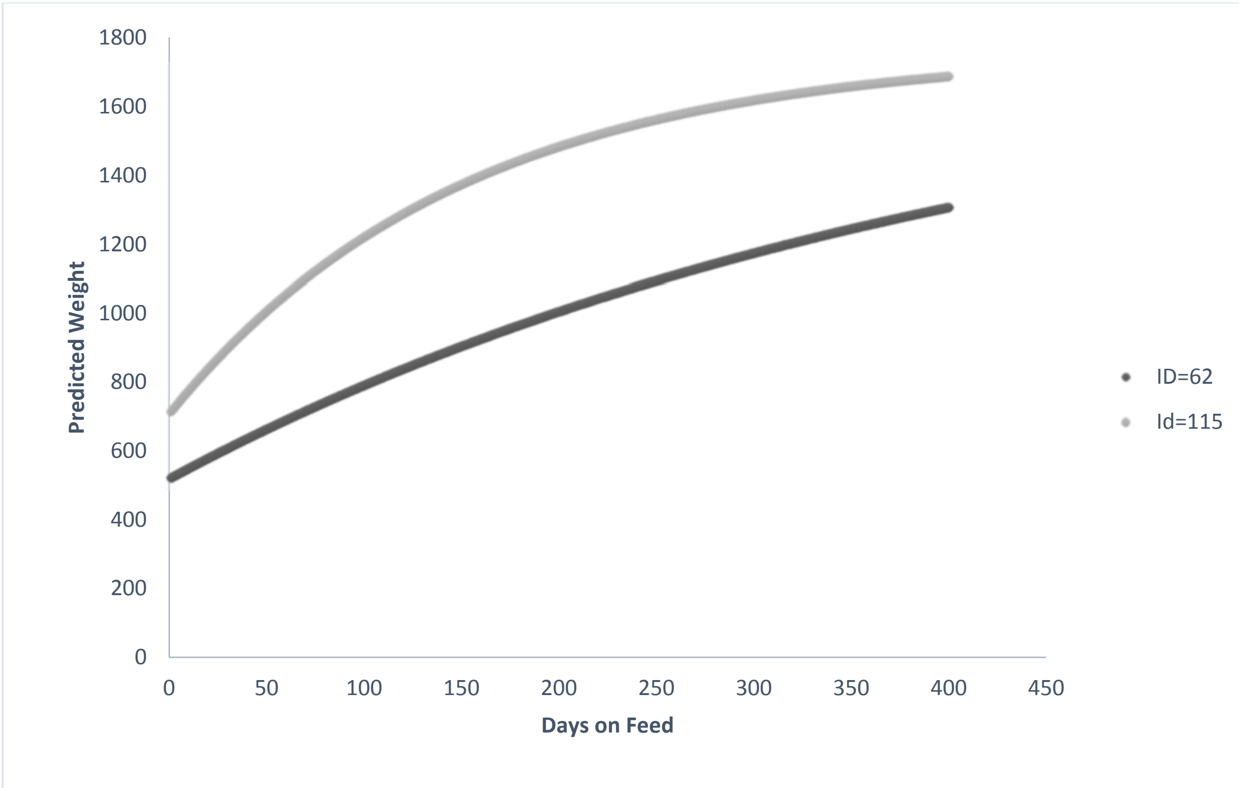


Figure 1. **Days-on-feed Logistic Model** predicted weight over days on feed: ID=62 and ID=115.

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