Economics of Variable Swine Growth

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Abstract

This paper addresses the economic impacts of swine growth variability. Different
economic penalties are determined to be associated with over-finishing versus under-
finishing an animal. Marketing decisions based on the pen average are determined to be
insignificantly less than optimal for a case study data set of 350 swine. Sensitivity
analysis is conducted to determine the impact of increased growth and price variability.

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Introduction

The livestock industry typically markets an entire pen of animals at one time based on the average size. However, to be entirely confident about marketing decisions, the entire range of the data may need to be understood (Pringle, 2000). Averages mask information. This information might return more than it costs to collect. For example, ignoring information about variability in animal growth results in some animals being over-finished, while others have not yet reached their full economic potential at the time the pen is marketed. Furthermore, there can be different economic penalties associated with over-finishing compared to under-finishing an animal. Therefore, marketing decisions based on the average might be less than optimal.

Previous research on the optimal slaughter weight of livestock has focused on feeding strategies, genetics, and pricing systems (Boland, Preckel, and Schinckel, 1993; Chavas, Kliebenstein, and Crenshaw, 1985; Crabtree, 1977; Heady, Sonka, and Dahm, 1976). In general, this research has established decision rules based on a representative animal from the group. This may be appropriate in the poultry and hog industries where genetic variability has been reduced in recent years. However, these same decision rules may be sub-optimal for heterogeneous animals such as cattle, where there are frequent calls to improve quality and consistency (Smith et al. 1995 and NCBA). Grid marketing and complicated sorting systems (i.e. Brethour, 1989) that use ultrasound to identify individual animal traits show that the beef industry understands that economic losses can occur when pens are sold based on average animal traits.

Unfortunately, there is very little data that tracks individual animal performance while on feed, especially in the cattle industry. Craig and Schinkel are attempting to

address the variability in swine growth potential using a mixed effects econometric model. Their work shows promise in modeling variable animal growth. However, it does not address the economic decision process.

The objective of this paper is to determine the parameters that are important for optimal market timing of a pen of livestock, taking into consideration the full economic impact of the variability in animal growth potential. We address this issue by:

1) estimating a sigmoidal growth function that simulates the pen average weight through time;

2) developing a simulation model to capture the dynamics of the livestock distributed around this average at any point in time;

3) combining these two growth simulations to model the pen dynamics and to determine the optimal market date; and

4) using sensitivity analysis to determine which parameters, pen variability or price premiums/discounts, yield the highest benefit to collecting and using individual animal performance data.

Since we can find no data that is proprietary to cattle, we use data from the swine industry. Given that swine are likely to be a type of livestock that benefits most from averaging (because they are very homogeneous), we use this as the baseline projection. Then, using hypothetical variations in parameters such as pen variability, we determine what affects benefits to information most. This information can be used in turn to direct future research such as collecting data on cattle.

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This paper extends previous research in two ways. First, whereas previous research has focused on decision rules as they pertain to a representative animal for a given group, we are considering the entire distribution of animals. Therefore, the decision rules developed in this paper are a better representation for the full economic potential of all-in, all-out pen marketing practices. Second, the sensitivity of these decision rules to changes in growth variability and price/weight discounts are determined through parametric analysis. This provides important information in directing future research focused on individual animal performance within a group.

Background and Theory

We hypothesize that more profit can be made by marketing pens earlier than the date indicated by the pen average. The basis for this hypothesis is that the marginal value product associated with feeding the pen of hogs one more day is declining at an increasing rate. As such, the penalty associated with over-finished pigs is hypothesized to be marginally greater than the penalty associated with under-finished pigs assuming a constant hog price. Therefore, by adjusting the market date forward, economic gains can be realized.

For growing animals, the marginal factor cost associated with days on feed is increasing with time. It costs more each subsequent day to feed the animal, as it grows larger. Figure 1 shows the relationship for a representative hog in our data set. The optimal market date for this pig is 130 days of age. At this point, MVP=MFC. Suppose the pig is fed until day 140 to be marketed with a group. Then, from 130 days to 140 days MFC exceeds MVP. The shaded area between the curves to the right of the

MVP vs. MFC
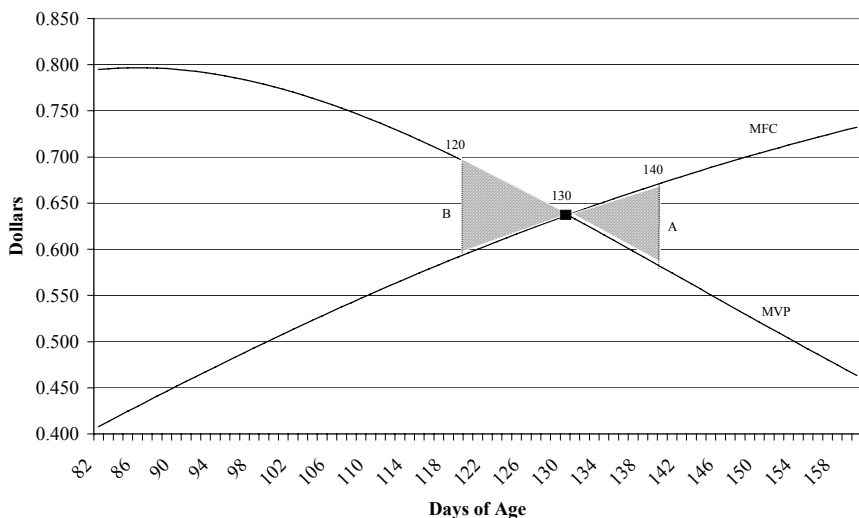
intersection point represents lost profits due to over-finishing the pig. If instead, the pig was in a group marketed at 120 days, then profits would be forgone. The shaded area to the left of 130 days represents profit that could have been realized if the pig were fed longer. We expect the area of A to be greater than the area of B. That is, the penalty associated with the *n* days of over-finishing an animal is greater than the penalty associated with the *n* days of under-finishing.

We want to determine if the penalty for over-finished pigs is greater than the penalty for under-finished and what the effect of this would be on the optimal marketing date for a complete pen of symmetrically distributed hogs.

Data and Methods

A panel data set consisting of twelve weight observations individually identified for 350 hogs every 1-3 weeks from 14 days of age to 171 days of age was obtained from Purdue University. The swine in the data set are all gilts taking part in a Purdue

University study on antibiotic treatments. Two different genotypes are represented in the data and the pigs are divided into 32 pens of approximately 10-12 pigs per pen. At any point in time, each pen is receiving the same ration fed ad libitum. Exactly half of the pens are given an antibiotic treatment. However, the selection of the treatment pens is done by random draw at the beginning of the trial and again at the beginning of the finishing phase. Therefore, the pens fall into one of four categories concerning antibiotic treatments: (1) treatment in both the nursery and finishing phase, (2) treatment in the nursery and no treatment in finishing, (3) no treatment in the nursery and treatment in finishing, or (4) no treatment in either the nursery or finishing.

The data set is first analyzed as if one growth path existed for the entire set of 350 hogs. Our data set was plagued by a common problem in animal growth modeling. The fastest growing pigs were marketed prior to the twelfth weight observation. Including all twelve observations to estimate our model parameters would downwardly bias the peak of the sigmoidal growth curve (Craig and Schinkel, forthcoming). Therefore, we eliminated the twelfth observation from any group calculations.

The use of a Gompertz sigmoidal curve to describe potential growth in swine has proved useful (Whittemore, 1993). The curve to give weight W_t at time t is given by

$W_t = Ae^{-be^{-kt}}$ where A is the upper asymptotic weight, k is a growth constant, and b is a time scale parameter.

Using the mean values for the entire group at each of the first eleven observations, we fitted a Gompertz growth curve to the data. This resulted in the following model as a representation of the growth path of the pen average.

$$W_t = 368e^{-4.19132e^{-0.014953t}} \qquad (R^2 = 0.9999)$$

At each observation, we assume the pigs are normally distributed around the growth path of the pen average. A standard deviation was calculated for the distribution at each of the eleven observations. The following linear model was estimated to simulate the growth in this standard deviation through time.

$$StdDev = 0.15t - 1.65 \qquad \left(R^2 = 0.983\right)$$

Finally, using the growth path of the pen average and the linear model for the growth in the standard deviation, we simulated the growth of the pen using an Excel spreadsheet simulation model.

The marginal cost side of the problem was limited to calculating feed costs. A naive, but practical formula, $F = 0.20W^{0.75}$, was adapted from Whittemore (1993) to represent pounds of daily feed intake, F, as a function of weight, W. A constant feed cost of \$0.06 per pound was assumed. Using this information and the above growth simulation, we simulated the daily cost of feeding the pen of growing pigs.

Combining the growth simulation model with an assumed hog price of \$0.44 per pound, we obtained a marginal value product for days on feed. This was compared to the daily marginal cost of feeding to determine the optimal day to market. As Figure 2 shows, our hypothesis turned out to be correct. The marginal value product is reduced when the calculation considers the entire distribution of weights instead of only considering the change in the average weight. However, the magnitude of the reduction is insufficient to warrant any action on the part of hog producers.

Figure 2:

Herd vs. Average Pig
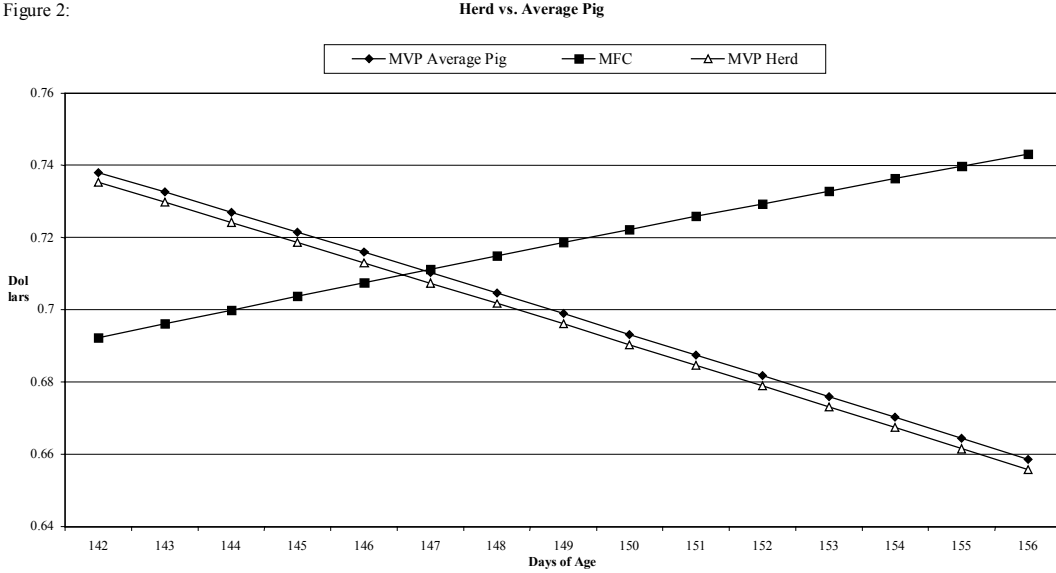
Hog producers that typically market based on the pen average would market the 350 pigs at 147 days of age as indicated by the intersection of MVP Average Pig and MFC in Figure 2. Our simulation model, however, takes into account the distribution of the pen around this average weight. According to our hypothesis, considering this distribution should warrant marketing the hogs earlier than the date indicated by the pen average. Our simulation, displayed graphically as MVP Herd, shows this is true. Therefore, the penalty for feeding an animal past the optimal date is greater than the penalty for marketing too early. However, there is very little curvature in the MVP and MFC curves around the optimal market date and the animals in the data set are relatively homogeneous. Therefore, the penalties are almost identical. As Figure 3 indicates, the simulation model, taking into account the effects of the distribution, suggests that the pen be marketed approximately one-half of a day earlier than the date indicated by using the

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pen average. We conclude that, for this case study, marketing a pen of hogs based on the average pig is sufficiently close to optimal.

Sensitivity Analysis

Our baseline example for hogs turns out to show that averaging is probably the best decision rule. However, how would the market timing change for a pen that is more heterogeneous or if there was a price penalty on over- or undersized livestock? One way to represent more heterogeneity is by expanding the variance in our model. When we take the linear model used to represent the growth in the standard deviation through time and generalize it with a slope parameter *m*, we get the following model.

$$StdDev = m \cdot t - 1.65$$

By varying the value of the parameter *m*, we can test the sensitivity of the model results to increased variance in animal size. A market timing decision based on average size is relatively unaffected by this increased variance. However, as table 2 indicates, more variance leads to an earlier market date if that decision takes into account the entire distribution of animals. The larger the variance, the further past optimal are some of the animals. The further the animal is past the optimal market date, the steeper the drop-off in its marginal value curve. Returns are increased by adjusting the market date earlier to avoid the large economic penalties associated with severe overfeeding.

Table 2:

Variance Growth Parameter (*m*)	0.15	0.20	0.25	0.30
Optimal Market Day for the Pen Distribution	147	146	142	136
Net Returns ($/Hd)	49.24	49.37	49.16	48.20
Optimal Market Day for the Pen Average	147	147	147	149
Net Returns ($/Hd)	49.24	49.37	48.94	46.22

As for price premiums or discounts, consider that our baseline model used a constant market price of 44 cents/lb. Suppose instead that we establish a pricing scheme based on the weight interval the animal falls into and the following pricing formula with the discount parameter δ.

$$price = 0.44 - \delta(240 - x)^2$$

We establish twenty pound weight intervals and use the pricing formula to determine the price for the entire interval based on the starting weight for the interval. In this way, the interval from 240-260 lbs. is established as the optimal market weight and receives the full price of 44 cents/lb. Table 3 summarizes pricing schemes for various values of the discount parameter and the optimal market timing determined by each of the two market timing decision methods, using the pen average and considering the entire distribution. Notice how quickly the decision method using the entire distribution adjusts to the pricing scheme by pushing the pen average toward the optimal pricing range. Even a modest discount scheme ($\delta = 1.5$ x 10^{-5}) produces a significant response in market timing using this decision method. Because the entire distribution is being considered in the decision method, the entire pricing scheme comes into play. The result is five more days on feed and an average animal weight of 239 lbs. Meanwhile, the decision method using only the pen average produces an overly simplistic response. Since the optimal average weight of 231 lbs. lies outside the optimal weight range of 240-260 lbs. any discounting scheme lowers the price received on that average animal. A slightly lower price results in a slightly lower marginal value curve and a slightly shorter time on feed. The loss generated by trying to feed the average animal from 231 lbs. up to 240 lbs. are

too great to be overcome by the higher price received when the 240 lb. range is reached. The best decision becomes is to stay in the 220-240 lb. range, accept the lower price, and market a little earlier.

Table 3

Discount Parameter				
δ (x 10^{-5})	0	1.5	2.5	3.5
Weight Range (lbs.)	Market Price			
< 200 *	0.44	0.386	0.35	0.314
200-220	0.44	0.416	0.40	0.384
220-240	0.44	0.434	0.43	0.426
240-260	0.44	0.440	0.44	0.440
260-280	0.44	0.434	0.43	0.426
280-300	0.44	0.416	0.40	0.384
300+	0.44	0.386	0.35	0.314
Optimal Market Day for the Pen Distributio	147	152	153	154
Average Weight	231	239	240	242
Net Returns ($/Hd)	49.24	47.15	45.88	44.64
Optimal Market Day for the Pen Average	147	146	145	144
Average Weight	231	229	228	226
Net Returns ($/Hd)	49.24	46.69	44.71	42.47

* using x=180 lbs. for the starting weight in the range.

Summary and Conclusions

This research provides useful insight about marketing pens of livestock. In the case of the swine industry, marketing groups of hogs based on the group average appears to be an economically sound technique. Accounting for the distribution of animals around the average indicates that the true optimal market timing for the pen is slightly earlier than that indicated by the pen average. However, the difference is insignificant.

When we expanded our example to include other situations that perhaps cattle or sheep producers might face, we found that expanding the variance led to earlier market dates when the entire distribution is considered in the decision making process. When we examined pricing schemes that involved discounts for animals outside of an ideal weight range, we found that decision methods using the entire distribution are, in general, more responsive to these pricing schemes. These methods seem to adjust quickly to push as much of the distribution as possible into the ideal weight range for pricing.

The insignificance of the differential in market timing for our baseline case study data is not totally unexpected. The swine industry has homogenized the genetics to the point that few distinguishable breeds exist in the feeding sector. Therefore, one would expect the average pig to be very representative of the group. Furthermore, since this study only considers weight and market timing as factors, this homogeneity condition is magnified. However, research has shown that a price premium or discount can be very effective in influencing the marketing weight of slaughter hogs (Chavas, Kliebenstein, and Crenshaw). Our sensitivity analysis seems to verify these findings as well as provide evidence of the need to consider the entire distribution of animals in market timing decisions in the presence of heterogeneity.

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