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# Estimating the Implicit Value of Management and Production Technology for Contractually Transferred Feeder Pigs

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Approximately one fifth of all market hogs slaughtered in the U.S. are sold as feeder pigs earlier in their lives (Rhodes). Prices for these feeder pig are established under a variety of market mechanisms. Most feeder pigs are sold through traditional public auctions so that the price of these feeder pigs is the price paid by the highest bidder. Other transfers take place through electronic feeder pig auctions which also establish prices as the amount paid by the highest electronic bidder. However, roughly one third of the feeder pigs are transferred directly from feeder pig producers to finishers (Hayenga et al. citing Crom and Dewar, 1980) and about half of these are transferred from contract farrow/nursery operations to contract grow/finish operations. Establishing prices for directly- or contractually-transferred feeder pigs is more difficult because they are not transferred through a focused, organized market where discovery of broad-based, publicly-shared prices can take place.

It is expected that direct and contract transfer of feeder pigs will become even more important in the future. For example, between 1982 and 1987, the structure of the feeder pig industry changed dramatically. While feeder pig volume relative to butcher hog marketings remained nearly constant, the number of feeder pig producers declined by 30%. As feeder pig producers become larger and more specialized, it is expected that contracts sales and sales by private negotiation will become more prevalent.

Normally, efficient prices result when a homogeneous commodity is traded in competitive auction markets. These prices can also be used in formulae to generate nearly efficient prices for transactions conducted via private negotiation. However, if the genetic quality of animals sold through private treaty differs substantially from the average auction animal, then the established auction prices will not accurately reflect the true social value of the animals sold through private treaty. Furthermore, the use of pricing formulae to value these animals will undervalue these animals if the formulae are based on the average genetics embodied in the auction animals.

In addition, feeder pigs values may depend on the grow/finish technology where they will be fed. Current breeds of domestic animals already perform differently under different environmental stresses and growing conditions. As

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genetic engineering techniques are applied to swine, it is possible to create feeder pigs that achieve different rates of gain in different grow/finish environments. In fact, large contract swine producers tend to utilize high-producing genetics in their production. The pigs which embody these genetics are typically obtained from breeding stock purchased from large, national seed-stock companies. Because the genetics in this stock are designed for optimal performance in intensely managed finishing technologies, contract swine producers try to control, within reasonable limits, the characteristics of their contracted grow/finish environments and have specified them to maximize the growth potential of their hogs. This matching of genetic characteristics with grow/finish technologies creates a specialized production process.

The value of a pig possessing superior genetics when combined with a customized production technology will tend to exceed the value which would be bid for the animal in a public market. Because of this, when large integrated feeder's feeder pig supplies exceed the amount that can be utilized in their grow/finish space, they often sell pigs to each other rather than sell pigs through public auction markets. Independent feeder pig producers who produce superior quality animals face the same kind of problem when attempting to sell their animals either through private treaty or in public markets.

In this research we estimate the value of the feeder pigs from common, high-performing genetics. These pigs were transferred from nurseries to a variety of grow/finish facilities. Unlike Schroeder, Jones and Nichols, we assume a high degree of uniformity in our feeder pigs due to their common, tightly-controlled genetic background. However, we account for variation in feeder pig values due to variation in the management and design of the facilities where the feeder pigs are fed. The results of this research suggest feeder pig price differentials for various grow/finish technologies. These differentials will assist in more accurate pricing of feeder pigs transferred under privately negotiated contracts. Our results can also provide a more accurate internal valuation of feeder pigs when a sale does not take place. This valuation is critical if an integrated hog producer's farrow/ nursery and grow/finish facilities are to be maintained as separate profit centers.

#### Theoretical Model

With a monthly production horizon, the pork production function is

$$y = f(x;Z) \quad (1)$$

where  $y$  is pounds of pork produced,  $x$  is a vector of variable inputs and  $Z$  is a vector of fixed inputs. In our specific case,  $x$  is a scalar representing the amount of feed fed and  $Z$  is a vector of fixed inputs with  $Z = [K, L, M, S]$ . For the fixed inputs,  $K$  represents capital,  $L$  represents labor,  $M$  represents management, and  $S$  represents the existing stock of animals on feed.

Capital and management are obviously fixed inputs because facilities, the main component of capital, and management typically cannot be varied during a production period as short as one month. Labor is assumed to be fixed in that labor requirements per unit of output are primarily dictated by the configuration of capital. Capital which is fixed implies fixed labor requirements. Beyond these basic requirements, labor can be increased but in the ab-

sence of other inputs, this additional labor will not obtain any additional output. Existing stocks of feeder animals are treated as fixed because within the monthly production period, these inventories are given. In a more general sense, these stocks include not only the number of head, but also the current weight of these animals.

Given this production function, the hog grower/finisher's short-run objective is to

$$\max \pi = p_y y - p^T x \quad (2a)$$

$$\text{s.t. } y = f(x; Z) \quad (2b)$$

where  $p_y$  is the price of the output  $y$ , and  $p^T$  is a row vector of prices with each element corresponding to a variable input. According to this standard profit maximization model, the value of an additional pig in the stock of feeder animals is

$$\partial \pi / \partial S = p_y \partial y / \partial S \quad (2c)$$

If this additional pig weighs fifty pounds, then (2c) establishes the implicit value of a fifty pound feeder pig. Empirically, two paths are available to establishing the desired result in (2c). These are either to estimate the production function and then derive  $\partial y / \partial S$ , or to estimate the profit function and then derive  $\partial \pi / \partial S$ . We will proceed along the latter path.

Sidhu and Baanante used a translog formulation to model the maximized profit function. This translog profit function uses a second-order logarithmic Taylor series expansion of profit in terms of the prices of the variable inputs and the quantities of the fixed inputs. The general formulation of a translog profit function is

$$\ln \pi^* = \mu + \sum_i \alpha_i \ln p_i^* + \sum_j \beta_j \ln Z_j + \frac{1}{2} \sum_i \sum_k \Gamma_{ik} \ln p_i^* \ln p_k^* + \sum_i \sum_j \Phi_{ij} \ln p_i^* \ln Z_j + \frac{1}{2} \sum_j \sum_h \Theta_{jh} \ln Z_j \ln Z_h \quad (3a)$$

where subscripts  $i$  and  $k$  designate the  $n$  variable inputs, subscripts  $j$  and  $h$  designate the  $m$  fixed inputs,  $\pi^*$  is profit normalized by the output price (i.e.  $\pi^* = (\text{Total Revenue} - \text{Total Variable Costs}) / p_y$ ), and  $p_i^*$  is the price of the  $i$ th variable input normalized by the output price (i.e.  $p_i^* = p_i / p_y$ ).

The normalization of profits and input prices by output price ensures that the profit function is homogeneous of degree zero in input and output prices. It is also important to note that this normalization results in normalized profits being expressed as units of output. To see this, suppose

$$\pi = p_y y - p^T x$$

Then

$$\pi^* = \pi / p_y = y - (p / p_y)^T x = y (1 - (p / p_y)^T x) = y (1 - \sum_i s_i)$$

where  $s_i = p_i x_i / p_y y$ . In order to express normalized profits in monetary units, normalized profits must be multiplied by the output price. For multi-



input production processes, the translog profit function displays symmetry. Most analyses utilize the translog profit function to derive input demand and output supply elasticities.

Our objective is to estimate the implicit value of an input. To accomplish this, it is more convenient to work with the profit function in the original (nonlogarithmic) data. Consequently, we will use a second order Taylor series approximation of the maximized profit function expressed as

$$\pi^* = \mu + \sum_i \alpha_i p_i^* + \sum_j \beta_j Z_j + \frac{1}{2} \sum_i \sum_k \Gamma_{ik} p_i^* p_k^* + \sum_i \sum_j \Phi_{ij} p_i^* Z_j + \frac{1}{2} \sum_j \sum_h \Theta_{jh} Z_j Z_h \quad (3b)$$

This function is also homogeneous of degree zero due to the use of normalized profits and prices. Symmetry of output responses is also expected. The parameters resulting from the estimation of (3b) can be used to estimate the implicit value of feeder pigs as  $\partial \pi^* / \partial S$  ( $S = Z_m$ ). The result will be

$$\beta_m + \sum_i \Phi_{im} p_i^* + \sum_j \Theta_{jm} Z_j, \quad (3c)$$

a linear function of the prices of the variable inputs and the quantities of the fixed inputs and the estimated parameters. When the function,  $\partial \pi^* / \partial S$  is evaluated it will return physical units of the output (pounds of pork). These physical units must be converted to monetary units by multiplying by the price of market hogs.

#### Data

Data obtained from Swine Graphics Enterprises (an integrated swine record-keeping, contracting and production management firm located in Webster City, Iowa) were used to estimate (3b). These data consisted of accounting records which were maintained under contract with producers during the January 1987 through December 1991 time period. Ninety-eight growing/finishing rooms were selected from a much larger population due to the uniformity of the genetic stock fed in these rooms.

Multiple grow/finish rooms were included for some farms while some rooms did not record data over the entire time period. In total, the data set contained 4,529 monthly observations from 22 different farms. The definition of a growing/finishing room was subject to each manager's discretion. For some farms, a grow/finish room was defined as a whole grow/finish building, or even a cluster of such buildings, while other farms adhered more closely to the concept of a single room. Data collected included pounds of pork generated in the room, average daily gain per pig, pounds of feed consumed per pound of gain, feed consumption per pig per day, average pig inventory (both head, HD, and weight, WT), cost of feed consumed per pound of pork generated, cost per ton of feed (PFD), and the sales price for hogs sold during the month.

In the theoretical model, capital was a fixed input which was assumed to be measurable on a continuous scale. The empirical measurement of capital relied on facility descriptions which were included in the data set. This information included facility type (indoor versus outdoor), ventilation (natural versus power), floor (slats, partial slats, solid concrete, concrete & dirt or

dirt), and waste disposal system. Based on this information, each facility was assigned to a class which best described the facility. These stylized facility classes then served as proxies for the capital used in the production process. In the regression analysis, dummy variables were used to indicate membership in a feeding facility capital-structure class. Capital structure descriptions used are: power ventilated indoor confinement facilities, naturally ventilated indoor confinement facilities, and outdoor facilities. The dummy variables IP, IN, and OU, respectively, are set to one to indicate that a facility is a member of a class (zero otherwise). As a set, these three dummy variables are referred to as TECH. The size of the feeding area, SP, measured in square feet and excluding walkways and service areas, serves as an additional measure of the capital employed.

In the theoretical model, management was also assumed to be a fixed input and measurable on a continuous scale. A set of dummy variables (MGT) were generated where each farm has its own unique dummy variable ( $MGT_i = 1$  if farm =  $i$ , 0 otherwise). In the empirical analysis, this set of dummy variables serves as a proxy for the continuous management input.

Two extremes of production strategies were evident in the data. Some producers kept records on finely divided facilities. This resulted in small feeding spaces and feeding appeared to take place under an all-in/all-out feeding regime. Under this process, the feeding space was filled with pigs of a uniform weight. These pigs were then fed to slaughter weight. The feeding space was emptied when the hogs were sent to slaughter, then refilled with a new batch of small pigs. At the other extreme, some producers kept records on larger conglomerations of many feeding spaces. These spaces appeared to have uniform flows of pigs of all weights through the facilities even though the pigs were segregated by weight within feeding spaces within the facilities.

The point of the distinction is that pork production seemed to be more variable in some facilities than in others, due to differences in record-keeping and, to a lesser extent, production strategies. These differences in variation between production facilities represent a classic case of heteroscedasticity which occurs when the different production facilities are combined in a common sample. Econometric theory establishes that heteroscedasticity causes ordinary least squares estimators to be inefficient and to give biased t-test results. Weighted least squares removes this inefficiency if the weights chosen result in a common variance for the weighted errors. Our estimation used weighted least squares where the inverse of each room's standard deviation of production over the entire sample served as the weight on each observation.

### Empirical Results

The results of estimating the nonlogarithmic profit function are summarized in table 1. The overall regression statistics indicate that of the 4,529 observations, 3,006 were used in the regression analysis. Most of the nonuse of observations was caused by incomplete information about the physical design of the facilities. The resulting regression had an  $R^2$  of 0.895. The regression was significant with the probability of a smaller F of 0.0001.

Most of the regression effects are significant and result in comparative static results that are consistent with a priori expectations. For example,

Table 1. Weighted least squares results of translog profit function estimation.

Overall Regression Statistics:

Observations = 3,006      Mean Square Error = 2,500.625 (2,950 dfe)  
 Regression F = 449.12       $R^2$  = 0.895  
 Probability > F = 0.0001 (56 and 2,950 df)

Parameter Estimates:

Variable	Description	Estimate	T(or F) for $H_0$ : Parameter(s)=0	Pr >  T  (Pr > F)
INTERCEPT		-2370.04836 B	-3.53	0.0004
PFD*	Normalized feed pr	923.30695	4.73	0.0001
MGT <sup>a</sup>	Largest effect	13937.16642 B	(1.32)	(0.1562)
	...			
	Smallest effect	-401.58175 B		
TECH	Indoor/pwr vent	-1807.95297 B	-3.96	0.0001
	Indoor/nat vent	-885.35275 B	-2.34	0.0192
	Outdoor	0.00000 B	.	.
SP	Space (sq ft)	-0.05106	-0.70	0.4864
HD	Inventory: Avg Head	35.49158 B	14.74	0.0001
WT	Inventory: Avg Wt	21.77137	5.48	0.0001
PFD* $\times$ PFD*/2		-2.18464	-2.61	0.0090
SP $\times$ PFD*		-0.00658	-0.38	0.7071
HD $\times$ PFD*		-5.87602	-27.44	0.0001
WT $\times$ PFD*		-8.47389	-7.29	0.0001
HD $\times$ MGT <sup>a</sup>	Largest	8.18736 B	(7.45)	(0.0001)
	...			
	Smallest	-25.91635 B		
HD $\times$ TECH	Indoor/pwr vent	9.27540 B	5.24	0.0001
	Indoor/nat vent	5.20508 B	3.09	0.0020
	Outdoor	0.00000 B	.	.
SP $\times$ SP/2		0.00000	1.10	0.2694
HD $\times$ SP		0.00013	1.18	0.2383
SP $\times$ WT		-0.00012	-0.73	0.4637
HD $\times$ HD/2		-0.01136	-3.43	0.0006
HD $\times$ WT		0.01807	2.36	0.0186
WT $\times$ WT/2		-0.00610	-0.45	0.6504

a/ MGT represents a set dummy variables, with one variable for each of the 20 different farms in the analysis. Nineteen different parameters estimate the effect of management. These parameters are summarized by reporting only the largest and smallest estimates. The associated F statistics test whether these effects are significant and are distributed as an F random variable with 19 and 2,950 degrees of freedom.



the expected impact on normalized profits of an increase in feed costs is negative. According to the estimation results

$$\partial \pi^* / \partial \text{PFD}^* = 923.3 - 2.185 \text{ PFD}^* - 5.876 \text{ HD} - 8.474 \text{ WT}$$

If this effect is evaluated at sample averages of HD (291.7 head) and WT (138.9 pounds), it will be unambiguously negative as well as have a negative slope on the (always positive) normalized price of feed. The second partial derivative,  $\partial^2 \pi^* / \partial \text{PFD}^{*2}$ , is negative (-2.185) indicating the concavity of the profit function.

It is evident from inspecting table 1 that all possible interactions between the dummy and the continuous variables were not included in the regression. These interactions were excluded to save degrees of freedom as each interaction between a continuous variable and the entire set of management and technology dummy variables requires 21 degrees of freedom (19 for farms and two for technologies). The included dummy variables account for different average profits for each farm and each facility type. The interactions of these dummy variables with HD imparts differing marginal valuations of HD for each farm and facility type.

The estimation results can also be used to derive the impact of the production facility characteristics on the value of feeder pigs. These impacts are highlighted and italicized in table 1 and correspond to the terms in  $\partial \pi^* / \partial \text{HD}$ . In general, this expression evaluates the marginal value one more head in inventory. If this additional head weighs roughly 50 pounds, then it is a feeder pig. This analysis introduces a slight complication because the addition of a 50 pound pig to inventory causes the average weight of the pigs in inventory to decrease slightly. For example, at the sample averages (HD = 291.7 head and WT = 138.9 pounds) the addition of one head weighing fifty pounds causes the average weight to drop .3 pounds. The magnitude of this effect is inversely related to the number of head on feed. If, for the sake of analytical convenience, we accept that this effect is negligible, then the  $\partial \pi^* / \partial \text{HD}$  establishes the implicit value of feeder pigs.

As can be seen from table 1, the value of feeder pigs is negatively associated with the price of feed (-5.876). The implicit price of feeder pigs also depends on management. The range of the adjustment for the management effect runs from 8.187 to -25.916. These effects are statistically significant. The production technology also influences the implicit value of a feeder pig. According to the results shown in table 1, a feeder pig is worth 9.275, and 5.205 more, respectively, to an indoor/power ventilated, and an indoor natural ventilated confinement facility than to an outdoor facility. The units on all of these coefficients are pounds of pork. These physical quantities can be converted to value measures by multiplying by the sample average of roughly \$0.50 per pound of pork. The dollar premia on the types of feeding spaces amount to roughly \$5.00 and \$2.50 per head, respectively.

The results in table 1 also indicate that hog feeders with greater space can afford to pay more (0.00013) for feeder pigs, although this amount is neither statistically nor materially significant. The results also indicate that the implicit value of a feeder pig tends to decline as a feeder has more head in inventory. This effect is consistent with the expectation that crowding



limited feeding space will result in less efficient feeding and hence lower implicit values on additional feeder pigs.

### Summary and Conclusions

The modeling effort reported in this paper can be refined and extended in several ways. First, typical applications of profit function methodology utilize Shephard's lemma (see Binswanger) which establishes that  $\partial\pi/\partial p_r = -x_r$ . If a corresponding derivative is found for the empirical profit function, (3b) the result is

$$\partial\pi^*/\partial p_i^* = \alpha_i + \sum_k \Gamma_{ik} p_k^* + \sum_j \Phi_{ij} Z_j \quad (4a)$$

The equivalence of  $\partial\pi/\partial p_r$  and  $\partial\pi^*/\partial p_i^*$  implies

$$-x_i = \alpha_i + \sum_k \Gamma_{ik} p_k^* + \sum_j \Phi_{ij} Z_j \quad (4b)$$

which can be added to the profit function and estimated as a seemingly unrelated regressions model with the appropriate restrictions across the two equations applied during estimation. Such a refinement should increase the statistics reported in table 1.

Second, the predictive ability of the model can be tested by comparing the estimated implicit feeder pig values to actual feeder pig values. The data set contains information on one hundred and three feeder pig transactions. These transactions include both feeder pig purchases and sales. Information available about these transactions includes weight, price and head bought or sold. The predictive ability of the model can be tested by generating the predicted implicit values of feeder pigs using equation (3c). These predicted values can then be regressed against actual prices. The regression goodness of fit ( $R^2$ ) indicates the predictive ability of the equation, and the regression intercept indicates the bias of the prediction. The predictive ability of the equation can also be tested by comparing price predictions against published feeder pig prices while recognizing that the pigs underlying the published prices have more pedestrian genetic backgrounds.

These shortcomings aside, the results reported here indicate that the profit function approach to establishing feeder pig values will be fairly reliable. The fit of the model to the data was fairly good, the signs and magnitudes of the estimated parameters were plausible, and the estimated parameters were mostly statistically significant. The derivation of a pricing formula based on the estimated profit function resulted in a formula that was also plausible. These results establish that for the type of hogs analyzed, a premium of roughly \$4.80 per pig can be paid if the pigs are going into indoor, power ventilated finishing facilities. Likewise, feeders that have indoor, naturally ventilated facilities can afford to pay a premium of \$2.60 per pig.

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