Impacts of PST on Optimal Production and Marketing Decisions of a Grow-Finish Hog Farm Operation

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This paper examines the impact of PST on the optimal production/marketing decisions of a grow-finish hog farm operation. The analysis evaluates PST from three angles: the feed efficiency effect, the leaner meat price effect, and the aggregate-supply-induced price effect. When limited to the feed efficiency effect only, the primary response to the new technology is to increase the animal turnover rate of the operation. When the leaner meat price effect is also included, marketing weight increases while turnover rate remains relatively unchanged. Additionally, if the increased aggregate supply depressed the market price by more than 10%, the benefits from improved feed efficiency and leaner meat will be completely dissipated. Aggregate price adjustments (reductions) of less than 10 percent maintained positive producer benefits resulting from improved feed efficiency and leaner meat.

Although somatotropins were discovered many years ago, only recent advances in recombinant DNA technology have made their commercial use economically feasible. Somatotropins are growth hormones which occur naturally in animals. Their supplemental use in livestock production have been shown to increase animal productivity. For example, bovine somatotropin (BST) has the effect of increasing milk production of dairy cows, while porcine somatotropin (PST) improves feed efficiency and carcass composition of pigs. Upon approval by the Food and Drug Administration, somatotropins will become available to dairy farmers and hog producers in the United States, necessitating both producer and industry level adjustments.

The purpose of this study is to evaluate the impact of PST on the optimal production and marketing strategies of a representative midwest grow-finish hog farm operation. While hog producers can increase production through use of PST without significant additional costs, they are facing the dilemma that the potential increased supply from technology adoption will likely lead to lower market prices, quickly absorbing any benefit from the improved production efficiency. However, due to the highly competitive nature of the industry in the United States and worldwide, the issue for the hog producer is not "to adopt or not to adopt." Rather, it is how to achieve optimality in the presence of the new technology.

The potential economic impacts of PST have been the focus of several studies.[1] Incorporating rather detailed production and financial characteristics of the farm, Lemieux and Richardson examined the financial consequences of adopting PST for a grain-hog operator under alternative market assumptions. Specifically, the authors focused on the effects of PST on such variables as net worth, equity ratio, cash receipts, and cash expenses. Using a linear elasticity model, Lemieux and Wohlgenant analyzed the market impacts of PST, including aggregate production, consumption, hog prices, and pork prices.

While competent and insightful, the above studies fail to address some of the firm level management issues important to hog producers. Given the new technology and its potential effect on the market price, to what extent should an individual producer optimally adjust his or her production and marketing decisions? In particular, the previous studies have treated as exogenous such key man-

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[1] The economic impacts of BST have also been subjected to scrutiny. For example, Kaiser, Scherer, and Barbano investigate consumers' perceptions and attitudes toward BST in milk, while Kaiser and Tauer simulate the aggregate effect of BST on U.S. Dairy markets.

agement decision variables as the desired combination of input usage, daily rate of gain, feeding length, and marketing weight and volume.

This article complements the previous studies by examining the optimal production/marketing decisions of an individual producer, given the PST technology and its potential effect on market prices. Section 2 provides an exposition of the model for a grow-finish hog farm operation; section 3 discusses how the base model is modified to account for the production and price effects of PST technology; section 4 discusses the simulation results; and section 5 presents the conclusions.

The Hog Farm Operation

A dynamic mathematical programming model is developed to simulate a grow-finish swine production operation. At the beginning of each month, the farm operator buys a desired number of feeder pigs with an exogenous weight of 40 pounds per head. The piglets are to be fed and then sold as market hogs within two to five months, including a one-month growing phase, and a one-to-four-month finishing phase. In the growing process the animal is fed to a body weight ready for finishing. A daily rate of gain of 1.54 pounds is selected for the growing pigs, based on the recommendation by the National Research Council (NRC). Given this exogenous daily rate of gain, a certain level of nutrients is needed. The required nutrients can be satisfied from a combination of feed inputs, determined by their relative costs and nutrient contents. Corn and soybean meal are the major feed ingredients which supply the required nutrients, including protein and energy. Data on nutrient requirements and nutrient contents are taken from the NRC.

Given a daily rate of gain of 1.54 pounds, the pigs weigh approximately 86 pounds per head when they enter the finishing phase. In the finishing process the animal is fed to a desirable marketing weight within one to four months, depending on economic incentives. Since the model allows for the purchase of feeder pigs each month, there is a maximum of four groups of finishing pigs at any given time, with the ith group in the ith month of the finishing operation. Accordingly, the model is of multiple cohorts and allows for continuous output of market hogs from month to month.[2]

Daily rate of gain in each month of the four-month finishing phase is specified as a function of the amount of nutrients consumed, given the initial weight at the beginning of the month. The growth equation estimated in Chavas et al. is adopted here:[3]

$$(1)\quad \begin{aligned} DRG_{i,t} = {} & 0.448154 \\ & + 0.63678\ LOG(PROTEIN_{i,t}) \\ & + 0.93737\ LOG(ENERGY_{i,t}) \\ & - 0.01237\ (WEIGHT_{i,t})^{0.75}, \\ & i = 1, \ldots, 4, \end{aligned}$$

where $WEIGHT_{i,t}$ (lbs) is the animal weight at the beginning of month t for those pigs entering the ith month of finishing; $DRG_{i,t}$ (lbs) is the daily rate of gain during month t for those pigs in the ith month of finishing; and $PROTEIN_{i,t}$ (lbs) and $ENERGY_{i,t}$ (1,000 Kcal) are the corresponding daily nutrient intakes per head. For a given desired level of daily rate of gain, (1) implies a certain amount of nutrient intake. Similar to the case of the growing operation, the required nutrients are satisfied from corn and soybean meal, depending on their relative costs and nutrient contents.

With the daily rate of gain in (1), the evolution of animal body weight for the finishing pigs is:[4]

$$(2a)\quad WEIGHT_{1,t} = 86,$$

$$(2b)\quad WEIGHT_{i,t} = WEIGHT_{i-1,t-1} + 30\ DRG_{i-1,t-1}, \qquad i = 2, 3, 4$$

$$(2c)\quad FEDWEIGHT_t = WEIGHT_{4,t-1} + 30\ DRG_{4,t-1},$$

where $FEDWEIGHT_t$ denotes fed hog weight after a four-month finishing phase. For simplicity, it is assumed that each month contains thirty days.

[2] Continuous (monthly) output through time has the advantages of "smoothing" out the farm operation and easing the cash flow problem.

[3] Chavas' growth function is applicable for the finishing phase of our study because the experimental data used in the estimation involves finishing pigs fed from an average body weight of 84.5 pounds to an average final weight of 227.5 pounds. Notice that equation (1) is slightly different from the one actually reported in Chavas et al., and was kindly provided by Jean-Paul Chavas. This alternative specification ignores an interaction term between energy and protein variables, which significantly mitigates the numerical problem encountered in the empirical optimization process.

[4] Given the numbers of feeder pigs purchased and the death rate incurred each month, the evolution of animal numbers can also be determined. The death rate is specified as 0.084% per month (Kliebenstein and Hillburn).

To fine tune the growth model in (1), this study also includes the following diet constraints for the finishing pigs:

$$\text{(3a)} \quad CORN_{i,t} + BEANS_{i,t} \leq \alpha_i \, WEIGHT_{i,t},$$

$$\text{(3b)} \quad PROTEIN_{i,t} \geq \beta_i \, (CORN_{i,t} + BEANS_{i,t}),$$

$$\text{(3c)} \quad PROTEIN_{i,t} \leq 0.2 \, (CORN_{i,t} + BEANS_{i,t}),$$

where $CORN_{i,t}$ and $BEANS_{i,t}$ are pounds of corn and soybean meal consumption per head for the ith month of finishing pigs, and α_i and β_i are coefficients pertaining to the ith group of animals.

Equation (3a) indicates the appetite of pigs with different body weights. Total amount of feed intake is restricted to no more than a certain proportion (α) of the animal body weight. The recommended α coefficients are 0.06, 0.055, 0.055, and 0.05, respectively, for pigs in the first, second, third, and fourth month of finishing (Christian). Equation (3b) specifies that protein intake should not be less than a certain proportion (β) of the total feed intake. The recommended β coefficients are 0.18, 0.17, 0.14, and 0.14, respectively, for pigs in the first, second, third, and fourth month of finishing (Christian). Finally, (3c) restricts the ration to contain no more than 20% protein, as discussed in Chavas et al.[5]

The above completes the discussion on the animal dynamics of the model. Animal body weight at the end of each month depends on the beginning animal weight and daily rate of gain for the month. The daily rate of gain for the growing pigs follows the one recommended by the NRC, whereas in the case of finishing it is endogenously determined. For a given daily rate of gain, a certain amount of nutrients is needed. The required nutrients for the growing pigs correspond to those reported in the NRC, whereas in the case of finishing they are dictated by the growth equation in (1). The required nutrients are satisfied from a combined usage of corn and soybean meal, depending on their relative costs and nutrient contents.

Subject to the production/marketing process discussed above, the objective function of the farm operator is to maximize the discounted net profit (return over variable costs) over a period of five years. The five-year monthly model runs from 1986 to 1990. A monthly discount rate of 1 percent is adopted. The return in each month include receipts from sales of market hogs, which are computed as: price per unit of weight * animal weight * number of animals sold. A premium/discount equation is estimated for the market hog price:

$$\text{(4)} \quad P = 49.836 + 0.107985 \, W - 0.0003 \, W^2,$$

where P is the price ($/cwt) for the market hog weighing W pounds.[6] Chavas et al. has provided evidence on the importance of allowing for hog prices to vary with animal body weight in empirical research. The magnitudes of the estimated coefficients in (4) are almost identical to those reported in Chavas et al.

Variable costs include expenses for feeder pigs, feed inputs, labor, and other non-feed related variable costs (such as medicine).[7] For a given number of animals, a certain number of labor hours is required per time period (i.e., per month), which can be satisfied from on-farm and hired labor. On-farm labor is specified as 200 hours per month. In addition, a facility constraint of 250 growing/finishing pigs per month is assumed for the representative farm.[8] Upon using the observed market prices to establish the terminal values of the animals, the dynamic optimization problem is solved by a nonlinear programming routine (Brooke et al.). Additional details on the model are provided in a report by Govindasamy et al.

Feeding Pigs with PST

The base model discussed above is adjusted to reflect production efficiency changes which would accompany the availability of PST technology. The growth hormone PST is administered monthly

[5] This is because the experimental data used in the estimation of the growth equation in Chavas et al. are based on a ration of less than 20%.

[6] The monthly data used in the price estimation include the years from 1986 through 1990, and were collected from *Agricultural Prices*.

[7] Feeder pig prices, feed input prices, wage rates, and other non-feed related variable costs are obtained from *Agricultural Prices*; and a Co-op Extension Service publication, Iowa State University. Data on labor requirements are from Holden.

[8] With an average feeding length of three months for the grower/finisher, this capacity implies feeding out about 1,000 hogs per year. This is consistent with an average hog farm operation in the Midwest (e.g., Stevermer).

via intramuscular injection to the finishing pigs.[9] Introduction of PST enhances the feed efficiency of the animal, leading to increased weight gain with fewer inputs (Boyd et al.). In addition, the animals also deposit more muscle relative to fat, resulting in leaner meat (Boyd et al.). However, higher protein levels are needed than for non-PST pigs (Kliebenstein et al.). The above effects of PST on finishing hogs can be intuitively understood by thinking of the growth hormone as having the equivalent effect of keeping the animal younger for a longer period of time. The total cost of PST is $2.77 per pig (Kliebenstein et al.).[10]

The feed efficiency effect of PST is incorporated into the base model by modifying the growth equation in (1) as

$$(1') \quad DRG_{i,t} = 0.448154 + (1 + \theta)\,[0.63678\ \mathrm{LOG}(PROTEIN_{i,t}) + 0.93737\ \mathrm{LOG}(ENERGY_{i,t})] - 0.01237\ FEDWEIGHT_{i,t})^{0.75},$$

where $(\theta * 100)$ is the percentage increase in feed efficiency due to PST. In surveying previous PST related studies, Boyd et al. found that feed efficiency improvements range from 13% to 29%, with the majority of the studies indicating an effect larger than 20%. Kliebenstein et al. reported a feed efficiency improvement of 25%. Based on the findings of the above studies, the coefficient θ is set as 0.25 ± 0.05.[11] To account for the need for greater protein intake, the coefficient β in (3b) is increased from 0.18, 0.17, 0.14, and 0.14 for the four finishing months to a common level of 0.18 for all months (Christian).

As mentioned, PST has the effect of producing leaner meat, although the animal is growing to a heavier weight. If the market is competitive, this leaner meat feature of PST should be reflected positively in price in the form of lower discounts for heavier market animals. The potential price effect of leaner meat from PST is incorporated into the base model by modifying the price equation in (4) as

$$(4') \quad P = 49.836 + 0.107985\ W - (1 - \phi)\ 0.0003\ W^2,$$

where $(\phi * 100)$ is the leaner meat price effect coefficient and captures the percentage reduction in price discount associated with heavier market weights.[12] Boyd et al. found that PST has the effect of increasing the amount of lean pork by about 10%. The coefficient ϕ is set as 0.10 ± 0.05. Assuming a typical market weight of $W = 250$, equation (4′) implies a live weight price premium of 1.61%, 3.23%, and 4.87% for $\phi = 0.05, 0.10$, and 0.15, respectively. These figures do not appear to be out of line with the 6.89% carcass premium (rather than live weight premium) for PST-treated hogs reported in Lemieux and Wohlgenant.

Finally, to account for changes in hog prices due to PST-induced changes in aggregate supply, equation (4′) is further modified as

$$(4'') \quad P = (1 - \zeta)\,[49.836 + 0.107985\ W - (1 - \phi)\ 0.0003\ W^2],$$

where $(\zeta * 100)$ is the percentage reduction in market price arising from an increase in the aggregate supply. Lemieux and Wohlgenant estimate the effects of PST on market hog prices under different assumptions on the length of run, adoption rate, and demand and supply elasticities. Averaging their various estimates for the short run (one year) and intermediate run (five years), a market price reduction of 7% is obtained. Based on their estimates, ζ is set as $7\% \pm 3\%$.

The Simulations

Four scenarios are considered including: (i) a base scenario of no PST; (ii) a PST scenario with only the feed efficiency effect; (iii) a PST scenario with both the feed efficiency effect and leaner meat price effect; and (iv) a PST scenario with the feed efficiency effect, leaner meat price effect, and aggregate-supply-induced price effect. In the second scenario, (1) is replaced by (1′) as the growth function for finishing pigs. In the third scenario, (1) is replaced by (1′), and (4) is replaced by (4′) as the market hog price equation. In the fourth scenario, (1) is replaced by (1′), and (4) is replaced by (4″). By comparing the latter three with the base scenario and averaging the result over the five-year maximization period, we obtain alternative mea-

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[9] It is necessary to administer PST via injection because the growth hormone is composed of amino acids and, hence, the stomach will simply digest the compound and render it ineffective if taken internally. Although the need for injection is one of the primary obstacles to the adoption of PST, many manufacturers are working toward developing improved delivery systems, such as long term implants.

[10] This is based on a rule-of-thumb pricing method often used in the animal health industry; namely, pricing a product at one third of the projected benefits from product use.

[11] Lemieux and Richardson as well as Lemieux and Wohlgenant assume a feed efficiency improvement of 24%.

[12] Some contend that consumers may be reluctant to consume pork from animals provided with PST. They argue that consumers' fear of product safety may deter consumption of PST pork, necessitating separate labeling and marketing. Others argue that the issue of increased leanness of PST pork will outweigh product safety concerns. However, little is known in this area and thus we have not considered price discounts for safety concerns.

sures of the impact of PST. The results are presented in Table 1.

Base Scenario: No PST

The first column of Table 1 indicates that in the base scenario of no PST the farm operator, on average, purchases approximately 75 feeder pigs each month. Recall that the piglets are to go through a one-month growing phase (to achieve a body weight of 86 pounds) and then a finishing phase of up to four months. The optimal solution indicates an average finishing time of 2.35 months. With 75 head of incoming feeder pigs per month and a growing/finishing feeding length of 3.35 months, the results suggest that, on average, the hog farm operates at a full capacity of 250 animals per month (75 * 3.35, adjusting for death loss). The optimal daily rates of gain for the fin-

Table 1. Optimal Solutions under Different Scenarios* **

	Base Scenario (No PST)	PST Scenario #1		
		$\theta = 0.20$	$\theta = 0.25$	$\theta = 0.30$
Column Number	[1]	[2]	[3]	[4]
Feeder pig purchases [head/month]	74.59	76.12 (2.06%)	76.38 (2.41%)	76.43 (2.48%)
Finishing time [months]	2.350	2.269 (−3.45%)	2.258 (−3.91%)	2.256 (−4.00%)
Daily rate of gain [lbs]	2.324	2.383 (2.54%)	2.390 (2.84%)	2.394 (3.01%)
Market weight [lbs]	249.9	248.3 (−0.67%)	247.9 (−0.81%)	248.0 (−0.78%)
Corn usage (lbs/head/day]	4.713	3.862 (−18.04%)	3.722 (−21.02%)	3.597 (−23.67%)
Soybean meal usage [lbs/head/day]	1.442	1.297 (−10.02%)	1.298 (−9.99%)	1.200 (−16.74%)
Energy intake [1000 Kcal/head/day]	9.438	7.905 (−16.25%)	7.611 (−19.36%)	7.351 (−22.12%)
Protein intake [lbs/head/day]	1.035	0.900 (−13.02%)	0.864 (−16.49%)	0.834 (−19.44%)
Discounted return over variable costs [$/month]	5271	5611 (6.44%)	5719 (8.50%)	5731 (8.73%)

	PST Scenario #2			PST Scenario #3		
	$\phi = 0.05$	$\phi = 0.10$	$\phi = 0.15$	$\xi = 0.04$	$\xi = 0.07$	$\xi = 0.10$
Column Number	[5]	[6]	[7]	[8]	[9]	[10]
Feeder pig purchases [head/month]	76.00 (1.90%)	60.78 (−18.52%)	60.92 (−18.32%)	60.76 (−18.54%)	60.64 (−18.69%)	61.22 (−17.92%)
Finishing time [months]	2.294 (−2.38%)	3.082 (31.15%)	3.087 (31.36%)	3.083 (31.19%)	3.089 (31.45%)	3.077 (30.94%)
Daily rate of gain [lbs]	2.397 (3.14%)	2.452 (5.51%)	2.452 (5.51%)	2.450 (5.42%)	2.450 (5.42%)	2.447 (5.29%)
Market weight [lbs]	251.0 (0.41%)	312.6 (25.09%)	313.1 (25.26%)	312.6 (25.09%)	313.0 (25.26%)	312.0 (24.82%)
Corn usage (lbs/head/day]	3.627 (−23.05%)	3.973 (−15.69%)	3.977 (−15.61%)	3.967 (−15.82%)	3.970 (−15.76%)	3.959 (−15.99%)
Soybean meal usage [lbs/head/day]	1.233 (−14.48%)	1.359 (−5.72%)	1.361 (−5.60%)	1.357 (−5.87%)	1.358 (−5.78%)	1.353 (−6.14%)
Energy intake [1000 Kcal/head/day]	7.444 (−21.14%)	8.168 (−13.47%)	8.176 (−13.37%)	8.155 (−13.59%)	8.161 (−13.53%)	8.136 (−13.80%)
Protein intake [lbs/head/day]	0.851 (−17.81%)	0.936 (−9.60%)	0.937 (−9.49%)	0.934 (−9.74%)	0.935 (−9.66%)	0.932 (−9.97%)
Discounted return over variable costs [$/month]	5862 (11.20%)	6080 (15.36%)	6388 (21.20%)	5733 (8.77%)	5471 (3.79%)	5247 (−0.46%)

*Figures in parentheses are percentage changes in the optimal solutions from the base scenario of no PST.
**PST scenario #1 accounts for feed efficiency effect, θ; PST scenario #2 accounts for feed efficiency effect ($\theta = 0.25$) and leaner meat price effect, ϕ; PST scenario #3 accounts for feed efficiency effect ($\theta = 0.25$), leaner meat price effect ($\phi = 0.10$), and aggregate-supply-induced price effect, ξ.

Table 2. Optimal Feed Usages and Nutrient Intakes per Hundred Pounds of Weight Gain in the Finishing Phase* **

	Base Scenario (No PST)	PST Scenario #1		
		θ = 0.20	θ = 0.25	θ = 0.30
Column Number	[1]	[2]	[3]	[4]
Corn usage [lbs/100 lbs weight gain]	202.8	162.1 (−20.09%)	155.7 (−23.21%)	150.3 (−25.91%)
Soybean meal usage [lbs/100 lbs weight gain]	62.0	54.4 (−12.28%)	54.3 (−12.47%)	50.1 (−19.22%)
Energy intake [1000 kcal/100 lbs weight gain]	406.1	331.7 (−18.32%)	318.5 (−21.58%)	307.1 (−24.39%)
Protein intake [lbs/100 lbs weight gain]	44.5	37.8 (−15.20%)	36.2 (−18.83%)	34.8 (−21.78%)

PST Scenario #2			PST Scenario #3		
ϕ = 0.05	ϕ = 0.10	ϕ = 0.15	ξ = 0.04	ξ = 0.07	ξ = 0.10
[5]	[6]	[7]	[8]	[9]	[10]
151.3 (−25.39%)	162.0 (−20.10%)	162.2 (−20.02%)	161.9 (−20.16%)	162.0 (−20.10%)	161.8 (−20.22%)
51.4 (−17.10%)	55.4 (−10.68%)	55.5 (−10.54%)	55.4 (−10.73%)	55.4 (−10.67%)	55.3 (−10.89%)
310.6 (−23.53%)	331.1 (−17.97%)	333.4 (−17.89%)	332.9 (−18.04%)	333.1 (−17.98%)	332.5 (−18.13%)
35.5 (−20.28%)	38.2 (−14.29%)	38.2 (−14.19%)	38.1 (−14.40%)	38.2 (−14.31%)	38.1 (−14.48%)

*Figures in parentheses are percentage changes in the optimal solutions from the base scenario of no PST.
**PST scenario #1 accounts for feed efficiency effect, θ; PST scenario #2 accounts for feed efficiency effect (θ = 0.25) and leaner meat price effect, ϕ; PST scenario #3 accounts for feed efficiency effect (θ = 0.25), leaner meat price effect (ϕ = 0.10), and aggregate-supply-induced price effect, ξ.

ishing pigs average 2.32 pounds, with a corresponding optimal marketing weight of about 250 pounds per head (86 + 2.324 * (2.356 * 30)).

The optimal corn usage per head per day is 4.71 pounds and optimal soybean meal usage is 1.44 pounds (also see Table 2).[13] The optimal energy intake is 9.44 thousand Kcal and protein intake is 1.04 pounds per day per head. Though not shown in the tables, it was found that the optimal corn-soybean meal ratio is 2.74, 3.18, and 5.45 for the first month, second month, and third month finishing pigs, respectively. This result is, in part dictated by the diet constraints in (3a) through (3c), and suggests that as the animals become older, their ration should contain proportionately more corn than soybean meal. Since corn is relatively higher in energy and soybean meal in protein, the result implies that older animals should have a higher energy-protein intake ratio than their younger counterparts; a result consistent with the feeding practice recommended by the NRC. The optimal energy-protein ratio is 8.50, 9.02, and 11.01 for the first month, second month, and third month finishing pigs, respectively. The discounted return over variable costs under the base scenario is $5,271 per month.

PST Scenario #1: Feed Efficiency Effect

In this scenario, the impact of PST is evaluated, considering only the feed efficiency effect. Initially, the coefficient θ in (1′) is set at 0.25. The results are presented in the third column of Table 1. Comparison with the base scenario of no PST shows that feeder pig purchases increase by 2.41% (to about 76 head per month). The average optimal finishing time decreases by 3.91% (to 2.26 months), indicating a higher turnover rate. The optimal daily rate of gain for the finishing pigs increases by 2.84% (to 2.39 pounds). The optimal marketing weight decreases slightly by 0.81% (to about 248 pounds per head).

As to the feed usage for the finishing pigs, there is a significant reduction of 21.02% in corn (to 3.72 pounds per day per head) but only a 9.99%

[13] Alternatively, Table 2 expresses the optimal feed usages and nutrient intakes for the finishing pigs on the basis of weight gain per hundredweight. The optimal corn and soybean meal usage per hundredweight of pork produced is 202.8 pounds and 62 pounds, respectively.

reduction in soybean meal (to 1.30 pounds per day per head).[14] The corresponding changes in nutrient intake are a reduction of 19.36% in energy (to 7.61 thousand Kcal per day per head) and a reduction of 16.49% in protein (to 0.86 pounds per day per head). The discounted return over variable costs per month increases by 8.50% (to $5,719).

The intuition behind the above results follows. Presumably, if PST has the effect of making the hog operation more profitable, the producer can better capture this profit potential by increasing the number of market hogs and/or their market weight. However, given the current premium/discount price system in (4), it is not optimal to increase the market weight because that would cause a reduction in the output price. Thus, an increase in the number of market hogs is achieved through buying more feeder pigs. Since the farm in the base scenario was already operating at full capacity, feeder pig purchases can be increased only if the turnover rate is also increased.

Since PST has the effect of increasing feed efficiency, daily rate of gain can be increased without any change in feed input. But this is not necessarily optimal; a reduction in feed usage is more desirable if the consideration for feed costs is important. In this case, the solution is dictated by a smaller increase in the daily rate of gain, accompanied by a reduction in feed usage. Finally, the differential rates of reduction in the consumption of corn vs. soybean meal and of energy vs. protein reflect the specification that PST-treated pigs require a higher protein ration than non-PST pigs.

The above analysis of PST impact is based on the assumption that the growth hormone increases the feed efficiency of finishing pigs by 25% (i.e., θ equals 0.25 in (1')). To examine the robustness of the solution, θ is respecified as 0.20 and 0.30. The results are in general robust, and reported in the second and fourth columns of Table 1. For such variables as feeder pig numbers, finishing time, daily rate of gain, and market weight, the optimal solutions change only slightly as θ varies. For feed usages and nutrient intakes, the optimal solutions vary modestly in percentage terms, though rather trivially in levels. Depending on θ, the impact of PST on feed usage ranges from -18.04% to -23.67% for corn, and from -9.99% to -16.74% for soybean meal. Correspondingly, the change in nutrient intake ranges from -16.25% to -22.12% for energy, and from -13.02% to -19.44% for protein.

PST Scenario #2: Feed Efficiency and Leaner Meat Effects

In this scenario, both the feed efficiency effect and leaner meat price effect are included in the analysis of PST impact. Initially, the leaner meat price effect coefficient ϕ in (4') is set at 0.10. The feed efficiency coefficient θ in (1') is set at its base level of 0.25 throughout this scenario.

The results are in the sixth column of Table 1. Comparison with the base scenario of no PST shows that feeder pig purchases decrease by 18.52% (to about 61 head per month). The average optimal finishing time increases by 31.15% (to 3.08 months). The optimal daily rate of gain for the finishing pigs increases by 5.51% (to 2.45 pounds). The optimal marketing weight increases by 25.09% (to about 313 pounds per head). As to feed usage for the finishing pigs, there is a reduction of 15.69% in corn (to 3.97 pounds per day per head) and a reduction of 5.72% in soybean meal (to 1.36 pounds per day per head).[15] The corresponding changes in nutrient intake are a reduction of 13.47% in energy (to 8.17 thousand Kcal per day per head) and a reduction of 9.60% in protein (to 0.94 pounds per day per head). The discounted return over variable costs per month increases by 15.36% (to $6,080).

Upon comparing the sixth and third columns of Table 1, it is found that the impacts of PST differ strikingly across scenarios, depending on whether the leaner meat price effect is included in the analysis or not. The effect of PST on daily rate of gain is about twice as much in PST Scenario #2 as in PST Scenario #1. Further, Scenario #2 results in a significant increase in finishing time and market weight, while Scenario #1 indicates slight reductions. Scenario #2 also marks a significant decrease in feeder pig purchases, while Scenario #1 suggests a slight increase. Finally, similar to PST Scenario #1, the current results indicate that PST has the effect of reducing feed usage and nutrient intake (on a per day per head basis). However, the reductions are smaller under the current scenario due to the longer feeding period.

The intuition is the following. With an explicit consideration for the leaner meat feature of PST in the current scenario, the optimal market weight is increased substantially because there is now less penalty associated with heavy weight. The increased animal weight is accomplished by a significant increase in finishing time and a modest

[14] Alternatively, Table 2 shows that corn and soybean meal usage per hundredweight of pork produced is reduced by 23.21% and 12.47%, respectively.

[15] Alternatively, Table 2 shows that corn and soybean meal usage per hundredweight of pork produced is reduced by 20.1% and 10.68%, respectively.

increase in daily rate of gain. Since the optimal finishing time is longer in the current scenario, there is less need for feeder pigs, resulting in a decline in their purchase. The reductions in feed usage and nutrient intake are smaller in the current scenario because of a higher daily rate of gain.

The above analysis is based on the assumption that the coefficient associated with the leaner meat price effect, ϕ, in (4′) is 0.10. A sensitivity analysis of respecifying ϕ as 0.05 and 0.15 is also conducted. The optimal solutions are rather robust as ϕ changes from 0.10 to 0.15 (column 7 of Table 1), but they become rather sensitive as the coefficient is decreased from 0.10 to 0.05 (column 5). In fact, the directions of the impact are reversed in this latter case for some variables, including feeder pig purchases and finishing time. In particular, when ϕ is 0.05, the directions of the impact for the above variables coincide more closely with those obtained under PST Scenario #1 (see column 3). This suggests that, with ϕ only at 0.05, the leaner meat price effect of PST is not large enough to motivate farmers to produce heavier weight hogs.

PST Scenario #3: Feed Efficiency, Leaner Meat, and Aggregate Supply Effects

Now, we investigate the full impact of PST, accounting for its feed efficiency effect, leaner meat price effect, and aggregate-supply-induced price effect. Initially, the aggregate-supply-induced price effect coefficient ζ appearing in (4″) is set at 0.07. The feed efficiency coefficient θ in (1′) and leaner meat coefficient ϕ in (4″) are set at their base levels of 0.25 and 0.10, respectively, throughout this scenario.

The results are in the ninth column of Table 1. Upon comparing with PST Scenario #2 (column 6), it is found that including the aggregate-supply-induced price effect of PST into the analysis does not affect the optimal management decisions in any important manner. Further, results from changing ζ to 0.04 and 0.10 (columns 8 and 10) indicate that the solutions are very robust for the range of ζ considered. However, the discounted profit varies significantly! Compared with the base scenario of no PST, the increase in discounted return over variable costs per month is 8.77% (to $5,733) when ζ is only 0.04, but becomes −0.46% (to $5,247) when ζ is 0.10. This indicates that if the aggregate supply change arising from the adoption of PST is to depress the market price by more than 10%, the benefit to producers from this new technology will be completely dissipated.

Conclusions

This paper examines the impact of PST technology on the optimal production/marketing decisions of a representative midwest grow-finish hog farm operation. Optimal decisions are investigated under four scenarios: (i) a base scenario of no PST; (ii) a PST scenario with only a feed efficiency effect; (iii) a PST scenario with both a feed efficiency effect and a leaner meat price effect; and (iv) a PST scenario with a feed efficiency effect, leaner meat price effect, and aggregate-supply-induced price effect.

The results show that impacts of PST on optimal management decisions vary strikingly, depending on whether or not a leaner meat price effect is included. With the model accounting only for the feed efficiency effect of PST, a primary response to the new technology is to increase slightly the pig turnover rate of the operation, accompanied by an increase in the daily rate of gain. Further, the results are quite robust within a wide range of the parameter regarding the assumption on PST feed efficiency impact.

On the other hand, where the leaner meat price effect coefficient of 10 percent or 15 percent from use of PST is also considered, a major response is to increase the marketing weight, accompanied by an increase in the daily rate of gain and finishing time. When the leaner meat price effect coefficient is only 5 percent, marketing weight does not increase from that without the price premium. This shows that the level of the lean meat price premium has a large impact on marketing weight. This points out the important role of leaner meat price effect in PST adoption. With the information provided in this study, adoption will be much more rapid with a 10 percent leaner meat price effect coefficient than with a 5 percent price coefficient.

Finally, the results also show that a farmer's profit from adopting the new technology depends crucially on how the market reacts to the PST-induced aggregate supply change. The only significant change from the scenario without the aggregate price reduction is reduced profits: marketing weight, time on feed, etc. for the scenario with the aggregate price reduction remain as they were. However, if the increased aggregate supply is to depress the market price by more than 10%, the benefit of PST arising from improved feed efficiency and leaner meat carcass composition will be completely dissipated.

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