Staff Papers Series

Staff Paper P90-10

February 1990

THE EFFECTS OF PORCINE SOMATOTROPIN
ON SWINE FEED COSTS

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The comments of Vernon Eidman, Bill Lazarus and Jeff Gillespie on an earlier draft of this paper are gratefully acknowledged. Remaining errors are the responsibility of the authors.

Staff papers are published without formal review within the Department of Agricultural and Applied Economics.

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Introduction

Among the many changes occurring in the swine sector, considerable interest has been shown in the potential economic impacts of the use of porcine growth hormone or somatotropin. Experimental trials of porcine somatotropin (PST) have provided a wide range of effects, but consistently indicate improvements in rate of growth and feed efficiency while producing leaner meat. The economic significance of PST relates to its potential impacts on both the demand for pork and the cost of pork production. The increased leanness attributable to PST could increase consumer demand, however, a negative consumer reaction to hormone treated pork is possible, also. Costs of production for swine growing and finishing operations may be lower with PST use due to the decrease in time on feed for a given market weight. PST may also reduce feed costs. The purpose of this paper is to report the results of an analysis of the potential impacts of PST on swine feed costs. Nutrient requirement and performance parameters with PST use are based on a statistical summary of published results of experimental trials. Least cost rations are estimated for various corn and soybean meal prices using a linear programming model. Ration and feed cost results are reported without PST use and with low, medium and high responses to PST administration.

Several economic analyses of PST appear in the literature. Examples include Meltzer, Lemieux and Richardson, and Hayenga, et al. These studies examined the firm or enterprise level economic impacts of PST. Hayenga et al. also estimated the sector level impacts over several years. All of the studies included feed cost effects of PST in the analyses. However, only point estimates of the response to PST were considered. In the study reported here, optimal rations are derived for a range of potential response rates to porcine somatotropin. Changes in feed costs are examined for various levels PST efficacy and over a range of market prices for ingredients.

The Linear Programming Model

The linear programming model was designed to find the ration which minimizes total feed cost per head. To do so, a least cost daily ration was derived for each of several stages of growth. By specifying several discrete stages of growth, the model was able to account for changing nutrient requirements and performance levels over time. The pigs were assumed to be fed ad libitum a diet which met minimum daily requirements of metabolizable energy, crude protein, lysine, calcium and phosphorus. The model may be described in detail as follows.

Minimize: $\sum_{i=1}^{n_f} p_i Y_i$ Total Feed Cost [1]

Subject to: $-Y_i + \sum_{j=1}^{n_s} d_j X_{ij} \le 0 \quad i=1 \ldots n_f$ Total Feed Use [2]

$\sum_{i=1}^{n_f} a_{1i} X_{ij} \ge b_{1j} \quad j=1 \ldots n_s$ Metabolizable Energy [3]

$\sum_{i=1}^{n_f} a_{2i} X_{ij} \ge b_{2j} \quad j=1 \ldots n_s$ Crude Protein [4]

$\sum_{i=1}^{n_f} a_{3i} X_{ij} \ge b_{3j} \quad j=1 \ldots n_s$ Lysine [5]

$\sum_{i=1}^{n_f} a_{4i} X_{ij} \ge b_{4j} \quad j=1 \ldots n_s$ Minimum Calcium [6]

$$\sum_{i=1}^{n_f} a_{4i}X_{ij} \leq 1.15b_{4j} \quad j=1\ldots n_s \qquad \text{Maximum Calcium} \quad [7]$$

$$\sum_{i=1}^{n_f} a_{5i}X_{ij} \geq b_{5j} \quad j=1\ldots n_s \qquad \text{Phosphorus} \quad [8]$$

$$\sum_{i=1}^{n_f} a_{6i}X_{ij} = b_{6j} \quad j=1\ldots n_s \qquad \text{Dry Matter Intake} \quad [9]$$

$$Y_i\ ,\ X_{ij} \geq 0 \quad j=1\ldots n_s;\ i=1\ldots n_f \qquad [10]$$

Where: n_s is the number of stages of growth

n_f is the number of alternative feeds

Y_i is the total per head use of feed i

X_{ij} is the daily per head use of feed i in stage j

p_i is the unit price of feed i

d_j is days on feed in stage j

a_{ki} is the content of nutrient k per unit of feed i
k=1: metabolizable energy   4: calcium
2: crude protein   5: phosphorus
3: lysine   6: dry matter

b_{kj} is the daily requirement of nutrient k in stage j
k=1: metabolizable energy   4: calcium
2: crude protein   5: phosphorus
3: lysine   6: dry matter

The objective function, equation 1, is total feed cost per pig, which is to be minimized. Constraint 2 defines the total use of each feed as the sum over all stages of daily use times the number of days in each stage. Constraints 3, 4, 5, 7 and 8 insure that minimum daily requirements are met for metabolizable energy, crude protein, lysine, calcium and phosphorus, respectively. Dry matter intake is fixed by constraint 9. Constraint 7 limits calcium intake to no more than 115% of the minimum daily requirement.

To analyze the impacts of PST on feed costs, the days on feed coefficients (d) and daily nutrient requirements (b) in the linear programming model were estimated for low, medium and high responses to PST. Because the change in cost associated with PST adoption is strongly influenced by feed prices (p), the model was solved for various price combinations, also.

The Data

Five stages of growth were defined for the analysis. They were 10 to 20, 20 to 50, 50 to 110, 110 to 170 and 170 to 230 pounds. Administration of PST was considered in stage 3, 4 and 5. Published data were compiled on the response to PST and were used to estimate parameters for an average, low and high response to the growth hormone in the three weight ranges. The results are summarized in Table 1. The references footnoted in Table 1 were used in deriving the response parameters. Several other papers were useful in compiling these data, also [Bark, Stahly and Cromwell; Boyd et al.; Convey; Smith, Kasson and Paulissen]. To estimate the parameters, average body weight, dose of PST and the response to PST as a percentage change from the control group were described by simple univariate statistics. Then, a quadratic dose response curve was estimated by ordinary least squares. A single dose of PST representing expected industry practices (4 mg per day) was selected based on the assumption that a long term implant technology would be used. The expected change in rate of gain and feed conversion was predicted for the PST treated pigs using the dose response curve. The expected response was compared to published results for similar cases and anomalies were resolved. The expected percentage change was then applied to the estimates of standard performance obtained by inspection of recent University of Minnesota performance data. Low and high estimates were obtained by subtracting and adding, respectively, one standard deviation to the average response.

Estimates of rate of gain for the no PST case and the three levels of response to PST were used to calculate days on feed in each stage -- parameter

Table 1: Summary of Alternative Scenarios Considered for the Response to PST.

Scenario	PST mg/day	Stage	Beginning Wt (lb)	Ending Wt (lb)	Days Fed	Protein Fed (%)	Rate of Gain lb/day	Feed Conversion
No PST[a]	NA	1	10	20	17	20	0.59	1.72
		2	20	50	31	17	0.97	2.23
No PST	NA	3	50	110	36	16	1.67	3.15
		4	110	170	33	14	1.80	3.35
		5	170	230	30	13	2.00	3.50
Low	4	3[b]	50	110	32	20	1.84	2.84
		4[c]	110	170	30	17	1.98	3.05
		5[d]	170	230	30	17	2.00	3.30
Average	4	3[b]	50	110	28	20	2.01	2.52
		4[c]	110	170	27	17	2.16	2.75
		5[d]	170	230	28	17	2.10	3.00
High	4	3[b]	50	110	24	20	2.18	2.20
		4[c]	110	170	24	17	2.34	2.45
		5[d]	170	230	26	17	2.20	2.70

[a] PST was administered only in stages 3, 4 and 5.

[b] For the 50-110 lb. weight range (stage 3), estimates of the response to PST are based on Steele, Campbell and Caperna; Caperna et al.; Campbell et al.; Evans et al.; and Ender et al.

[c] For the 110-170 lb. weight range (stage 4), estimates of the response to PST are based on Ender et al.; Knight et al.; Machlin; Goodband et al.; Baile, Della-Fera and McLaughlin; Bechtel et al., and Jones et al.; Bryan et al.; Newcomb et al.; Campbell and Taverner; Evock et al.; Etherton et al., 1987; Etherton et al., 1986; Chung, Etherton and Wiggins; McKeith et al.; Boyd, Wray-Cahen and Krick.

[d] For the 170-230 lb. weight range (stage 5), estimates of the response to PST are based on Boyd, Wray-Cahen and Krick; Azain et al.; Knight et al.

d_j.[1] The righthand sides of the intake constraints, levels of dry matter intake per day, were calculated as the product of rate of gain and feed conversion estimates in Table 1. Administration of PST causes an increase in muscle accretion while decreasing feed intake. Therefore, the concentration of protein in the diet must be increased to assure that the associated nutrient demands are met. The minimum daily crude protein requirements, b_{2j}, were set to the percentages of dry matter intake indicated in Table 1. Daily requirements of metabolizable energy, lysine, calcium and phosphorus were calculated based upon the National Research Council (NRC) Nutrient Requirements for Swine.[2] For the rations with PST, increases in the lysine requirements (b_{3j}) were increased in proportion to the increases in crude protein requirements. The daily nutrient requirements used in the analysis are given in Table 2.

The least cost rations were constructed using corn grain, soybean meal (dehulled), calcium carbonate, dicalcium phosphate, a vitamin and mineral premix and tallow.[3] The nutrient compositions of the feeds were taken from the NRC Nutrient Requirements for Swine and are summarized in Table 3. The values in Table 3 were used for the a_{ki} parameters. Monthly feed price data for Minneapolis were collected for 1988 and 1989 from Feedstuffs magazine. The averages of these 24 monthly prices were used as the base feed prices. The average prices for corn and soybean meal were $2.40 per bushel and $12.06

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[1] Specifically, total gain in each stage was divided by the corresponding estimate of daily rate of gain to get days on feed for the stage.

[2] For each nutrient, the daily requirement was regressed on animal weight using the NRC nutrient requirement tables. Then for each stage in the LP model, the average weight for the stage was used in the estimated equation to get the daily nutrient requirement for that stage.

[3] Tallow was added as an option when the energy requirements in stage five could not be met with the high response to PST (and the associated low intake).

Table 2: Nutrient Reguirements.

Stage	Metabolizable Energy (mcal/day)	Crude Protein (g/day)	Lysine (g/day)	Calcium (g/day)	Phosphorus (g/day)
		Without PST			
1	1.490	91.4	5.16	3.60	3.01
2	3.191	164.2	8.31	6.60	5.56
3	6.374	312.5	14.80	11.78	9.86
4	9.228	394.9	18.30	15.31	12.51
5	10.496	416.4	19.26	15.01	11.61
		With PST			
3	6.374	390.6	18.51	11.78	9.86
4	9.228	479.5	22.23	15.31	12.51
5	10.496	544.2	25.17	15.01	11.61

Table 3: Composition of Feeds, Per Pound as Fed.

Feed	Dry Matter	Metabolizable Energy	Crude Protein	Lysine	Calcium	Phosphorus
Corn	0.880lb	1.551mcal	38.6g	1.1g	0.1g	1.3g
Soybean Meal	0.900	1.535	220.0	14.2	1.2	2.9
Calcium Carbonate	1.000	0.000	0.0	0.0	172.4	0.0
Dicalcium Phosphate	1.000	0.000	0.0	0.0	119.3	82.0
Vit/Min Premix	1.000	0.000	0.0	0.0	0.0	0.0
Tallow	1.000	3.581	0.0	0.0	0.0	0.0

per hundredweight, respectively. Because of the substitution of soybean meal for corn when PST was used, feed costs were estimated at high and low corn and soybean meal prices. Using the same 24 months of prices, standard deviations were calculated, then subtracted from the averages to get the low prices and added to the averages to get the high prices. The resulting low and high prices for corn were $2.07 and $2.74, respectively. The low and high prices for soybean meal were $10.37 and $13.76, respectively. The LP model was solved using the nine combinations of corn and soybean meal prices to estimate least cost rations for pigs not receiving PST and for each of the three PST response scenarios.

Results

Least cost daily rations for pigs no receiving PST for each stage of growth are given in Table 4. This solution was derived with corn and soybean meal prices at their average levels of $2.40 per bushel and $12.06 per hundredweight, respectively. Table 5 has the minimum cost solutions, including total feed use per head and feed use per day during stages in which PST is administered, for the no PST case and each of the three growth hormone responses. Per head use of corn changes from 665.9 pounds without PST to 576.8, 518.6 and 447.3 pounds with low, average and high responses, respectively. At the same time, soybean meal use per head changes from 92.4 pounds to 128.4, 124.7 and 125.2, respectively. The decrease in total corn use occurs as the daily protein requirement increased with PST administration and daily feed intake declines. While daily use of soybean meal increases with the increased response to PST, total use of soybean meal declines as time on feed declined from 141 days for pigs with a low response to PST to 134 and 128 days for pigs with an average and high response, respectively (total days

Table 4: Least Cost Daily Rations Without PST by Stage.

Feed	Pounds Per Day by Stage 1	2	3	4	5
Corn	0.81	1.95	5.22	5.85	6.99
Soybean Meal	0.30	0.43	0.63	0.82	0.80
Calcium Carbonate	0.01	0.02	0.06	0.07	0.09
Dicalcium Phosphate	0.01	0.02	0.02	0.03	0.00
Vitamin/Mineral Premix	0.01	0.01	0.03	0.04	0.04
Tallow	0.00	0.00	0.00	0.00	0.00

Table 5: Least Cost Rations.

Feed	No PST	PST Response Low	Average	High
	Pounds Per Head			
Corn	665.9	576.8	518.6	447.3
Soybean Meal	92.4	128.4	124.7	125.2
Calcium Carbonate	7.9	6.5	6.0	5.4
Dicalcium Phosphate	2.8	2.1	2.1	2.4
Vitamin/Mineral Premix	3.9	3.7	3.5	3.3
Tallow	0.0	0.0	0.0	4.7
	Pounds Per Day, Stage 3			
Corn	5.22	4.90	4.68	4.31
Soybean Meal	0.63	0.92	0.96	1.02
Calcium Carbonate	0.06	0.05	0.05	0.05
Dicalcium Phosphate	0.02	0.01	0.01	0.02
Vitamin/Mineral Premix	0.03	0.03	0.03	0.03
Tallow	0.00	0.00	0.00	0.00
	Pounds Per Day, Stage 4			
Corn	5.85	5.48	5.34	4.89
Soybean Meal	0.82	1.22	1.24	1.32
Calcium Carbonate	0.07	0.06	0.06	0.06
Dicalcium Phosphate	0.03	0.02	0.03	0.03
Vitamin/Mineral Premix	0.04	0.04	0.04	0.04
Tallow	0.00	0.00	0.00	0.00
	Pounds Per Day, Stage 5			
Corn	6.99	5.89	5.48	4.75
Soybean Meal	0.80	1.44	1.51	1.64
Calcium Carbonate	0.09	0.07	0.07	0.07
Dicalcium Phosphate	0.00	0.00	0.00	0.01
Vitamin/Mineral Premix	0.04	0.04	0.04	0.04
Tallow	0.00	0.00	0.00	0.17

on feed was 147 without the growth hormone).

Table 6 shows per head feed costs for pigs not receiving PST and for each of the PST response levels, including total feed cost and feed cost in each of the stages of growth in which PST is administered. The changes in feed costs from the no PST case are also shown in Table 6. Without PST, total feed cost was $40.61 per head. With PST, per head feed costs are $40.96, $38.00 and $35.80 for low, average and high response rates, respectively. Feed cost increased $0.35 per head with the low response, but decreased $2.61 with an average response and $4.80 with a high response level. Regardless of the response rate, feed cost per head declined with PST use in stages 3 and 4. However, in stage 5 (170 to 230 pounds), feed costs increase except in the case of a high response to the growth hormone. Regardless of the rate of response, most of the savings in feed cost occurs in Stages 3 and 4.

Because of the substitution of soybean meal for corn when PST is used, the prices of the two feeds are critical in determining the relative feed costs. In Table 7, the feed costs per head are given for each of nine corn and soybean meal price combinations.[4] Table 7 also shows the change in feed cost resulting from PST use. The percentage change in total feed cost is given in Figure 1 -- Figure 2 shows the percentage change for each of the stages in which the growth hormone is administered. Recall that the average of 1988 and 1989 monthly corn prices was $2.40 per bushel. The average for soybean meal was $12.06 per hundredweight. Low and high prices, calculated by subtracting and adding one standard deviation from the means, were $2.07 and $2.75, respectively, for corn -- $10.37 and $13.76 for soybean meal. As would be expected, feed costs decline the most as a result of PST administration

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[4] Only slight changes occurred in the optimal rations for the price combinations considered, so those quantities are not reported.

Table 6: Feed Cost Per Head.*

	No PST	---- PST Response -----			----- PST Response -----		
		Low	Average	High	Low	Average	High
Total Feed Cost	40.61	40.96	38.00	35.80	0.35	-2.61	-4.80
Stage 3 Feed Cost	10.97	10.62	9.58	8.63	-0.35	-1.39	-2.35
Stage 4 Feed Cost	11.98	11.81	10.75	9.69	-0.17	-1.23	-2.30
Stage 5 Feed Cost	12.06	12.93	12.08	11.90	0.87	0.02	-0.16

* Here, the corn price is $2.40 per bushel and the soybean meal price is $12.06 per hundredweight.

Table 7: Feed Cost Per Head by Corn and Soybean Meal Price.

		Feed Cost Per Head				Cost Change From No PST		
			PST Response			PST Response		
Corn Price	SBM Price	No PST	Low	Average	High	Low	Average	High
2.07	10.37	35.12	35.38	32.83	31.05	0.27	-2.29	-4.07
	12.06	36.68	37.55	34.94	33.17	0.87	-1.74	-3.51
	13.76	38.25	39.74	37.06	35.29	1.49	-1.19	-2.96
2.40	10.37	39.05	38.78	35.89	33.69	-0.26	-3.16	-5.36
	12.06	40.61	40.96	38.00	35.80	0.35	-2.61	-4.80
	13.76	42.18	43.14	40.12	37.93	0.96	-2.06	-4.25
2.74	10.37	43.04	42.24	38.99	36.37	-0.81	-4.05	-6.68
	12.06	44.60	44.41	41.10	38.48	-0.19	-3.50	-6.12
	13.76	46.18	46.60	43.23	40.61	0.42	-2.95	-5.56
		Stage 3						
2.07	10.37	9.49	9.17	8.28	7.45	-0.32	-1.21	-2.03
	12.06	9.87	9.68	8.76	7.93	-0.19	-1.11	-1.94
	13.76	10.25	10.18	9.24	8.40	-0.07	-1.01	-1.85
2.40	10.37	10.59	10.11	9.10	8.15	-0.48	-1.49	-2.44
	12.06	10.97	10.62	9.58	8.63	-0.35	-1.39	-2.35
	13.76	11.36	11.13	10.07	9.10	-0.23	-1.29	-2.25
2.74	10.37	11.72	11.07	9.94	8.86	-0.64	-1.78	-2.86
	12.06	12.10	11.58	10.42	9.34	-0.52	-1.68	-2.76
	13.76	12.48	12.09	10.90	9.81	-0.40	-1.58	-2.67
		Stage 4						
2.07	10.37	10.37	10.21	9.29	8.37	-0.16	-1.08	-1.99
	12.06	10.83	10.83	9.87	8.95	0.00	-0.96	-1.89
	13.76	11.30	11.46	10.46	9.52	0.16	-0.84	-1.78
2.40	10.37	11.52	11.19	10.17	9.11	-0.33	-1.35	-2.40
	12.06	11.98	11.81	10.75	9.69	-0.17	-1.23	-2.30
	13.76	12.45	12.44	11.34	10.26	-0.01	-1.11	-2.19
2.74	10.37	12.69	12.18	11.06	9.87	-0.50	-1.63	-2.82
	12.06	13.15	12.81	11.64	10.44	-0.34	-1.51	-2.71
	13.76	13.62	13.44	12.23	11.02	-0.18	-1.39	-2.60
		Stage 5						
2.07	10.37	10.42	11.16	10.42	10.38	0.74	0.01	-0.04
	12.06	10.82	11.89	11.15	11.14	1.07	0.33	0.31
	13.76	11.23	12.62	11.89	11.90	1.39	0.66	0.67
2.40	10.37	11.65	12.20	11.35	11.14	0.55	-0.30	-0.51
	12.06	12.06	12.93	12.08	11.90	0.87	0.02	-0.16
	13.76	12.47	13.67	12.81	12.66	1.20	0.35	0.19
2.74	10.37	12.91	13.26	12.29	11.92	0.35	-0.62	-0.99
	12.06	13.31	13.99	13.02	12.68	0.68	-0.30	-0.64
	13.76	13.72	14.73	13.75	13.44	1.00	0.03	-0.29

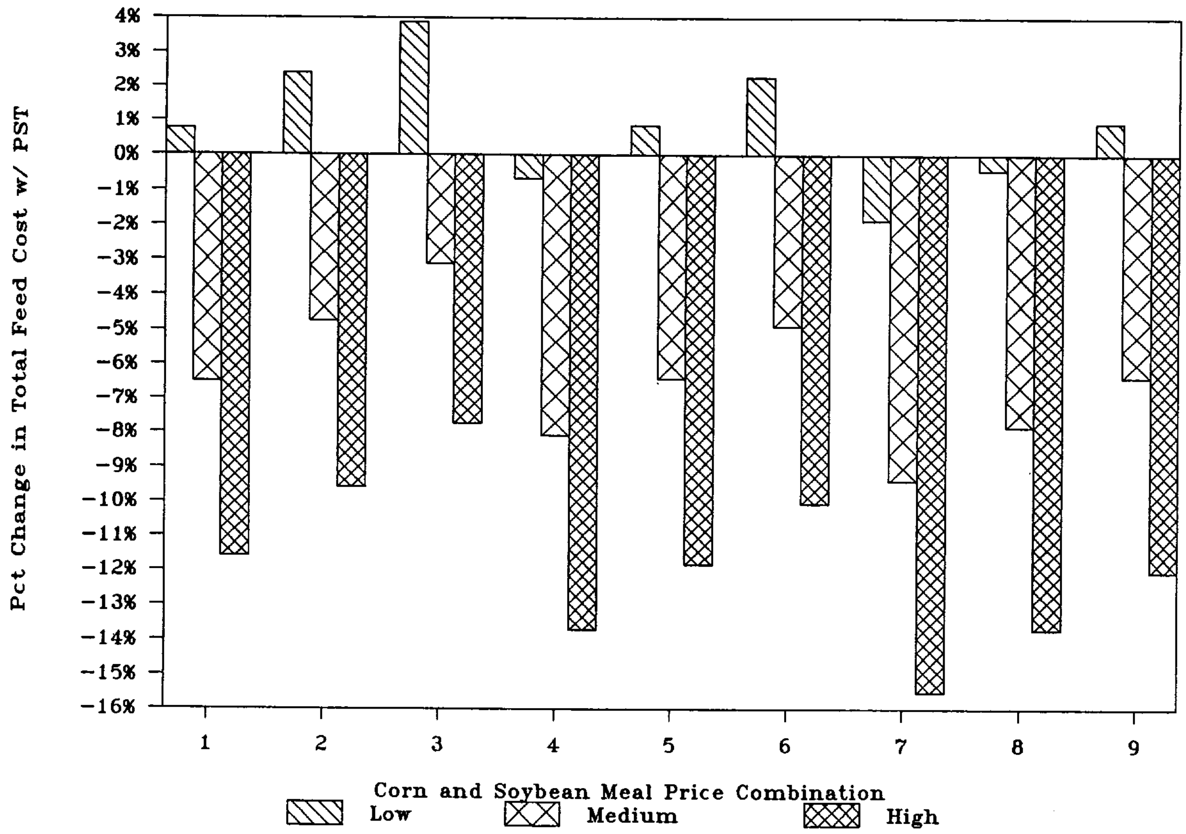

Figure 1: Percentage Change in Total Feed Cost Per Head for Each Rate of Response to Porcine Somatotropin by Corn/Soybean Meal Price Combination.*

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* For price combinations 1-3, 4-6 and 7-9, the corn price is $2.07, $2.40 and $2.74 per bushel, respectively. The price per hundredweight of soybean meal is $10.37 for price combinations 1, 4 and 7; $12.06 for 2, 5 and 8; and $13.76 for 3, 6 and 9.

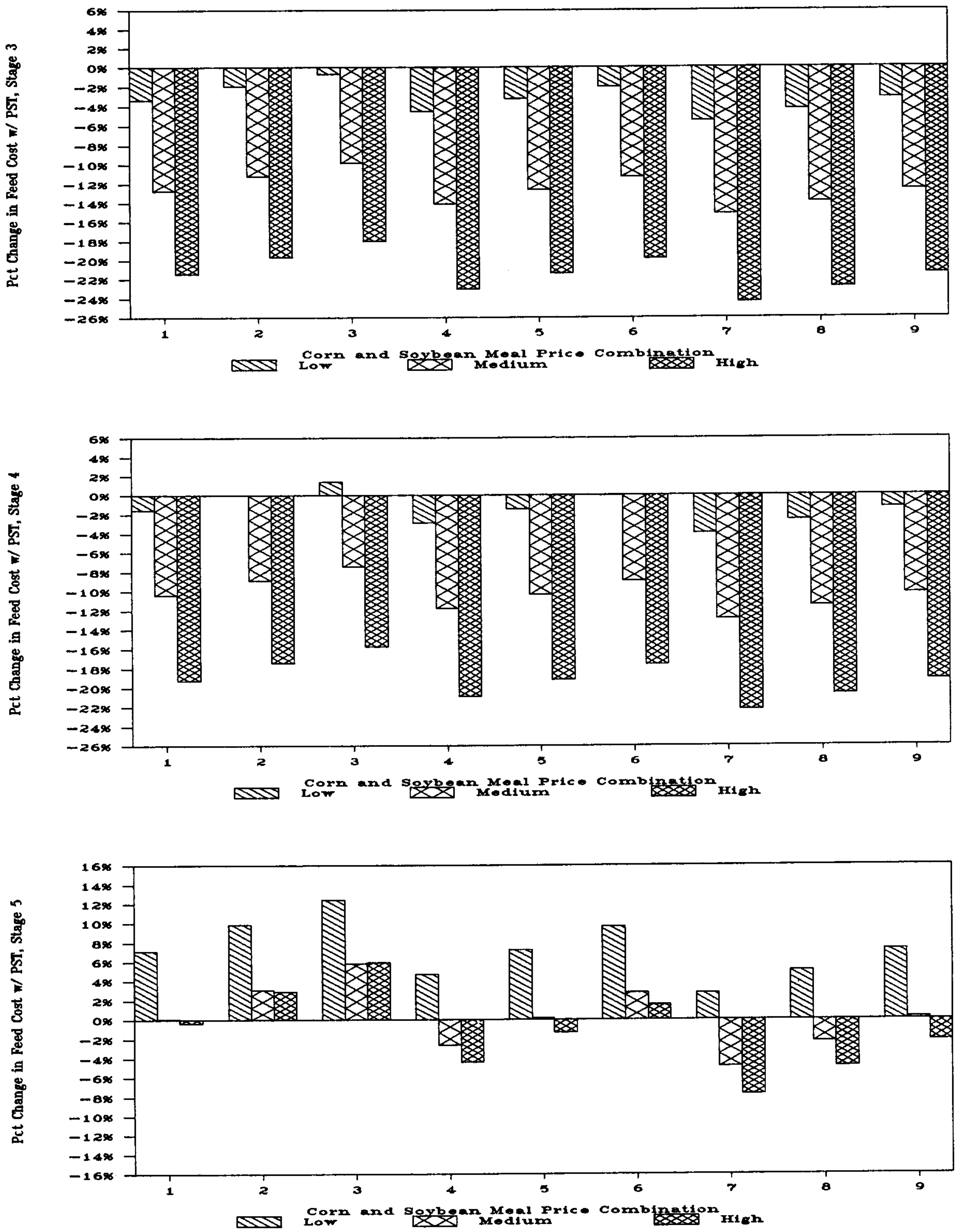

Figure 2: Percentage Change in Feed Cost in Stages in Which PST is Administered by Rate of Response and Corn/Soybean Meal Price Combination.

when the price of corn is high and the price of soybean meal is low. For this price combination, feed costs decline by $0.81 to $6.68 per head (1.9% to 15.5%). By contrast, when the corn price is low and the soybean meal price high, feed costs decline only $1.19 with an average and $2.96 with a high response to PST. For this price combination, feed costs increase by $1.49 when the response is low.

As was noted in the case of average prices, feed costs improve most in stage 3 and least in stage 5 when the growth hormone is used. With a high corn price and a low soybean meal price, feed costs decline in stage 3 by $0.64 to $2.86 -- 5.6% to 24.4%. With a low corn price and a high soybean meal price, stage 3 feed costs decline by $0.07 to $1.85. In stage 5, feed costs decline as a result of PST use in only 9 out of the 27 combinations of feed prices and response rates. The largest decrease in feed cost for this stage is $0.99 -- feed costs increase by $1.39 when the corn price is low, the soybean meal price is high and the response to the growth hormone is low.

Since feed use declines with the use of PST, the absolute prices of feed influence the relative feed costs. However, the substitution of protein for corn which accompanies the use of PST makes the price of soybean meal relative to the price of corn especially significant in explaining the cost change. Figure 3 illustrates this point. It shows the changes in total feed cost just discussed as a function of the soybean meal/corn price ratio. The feed cost advantage resulting from the growth hormone clearly declines as the price ratio increases. At all but the lowest three price ratios shown, feed costs increase when the response to PST is low.

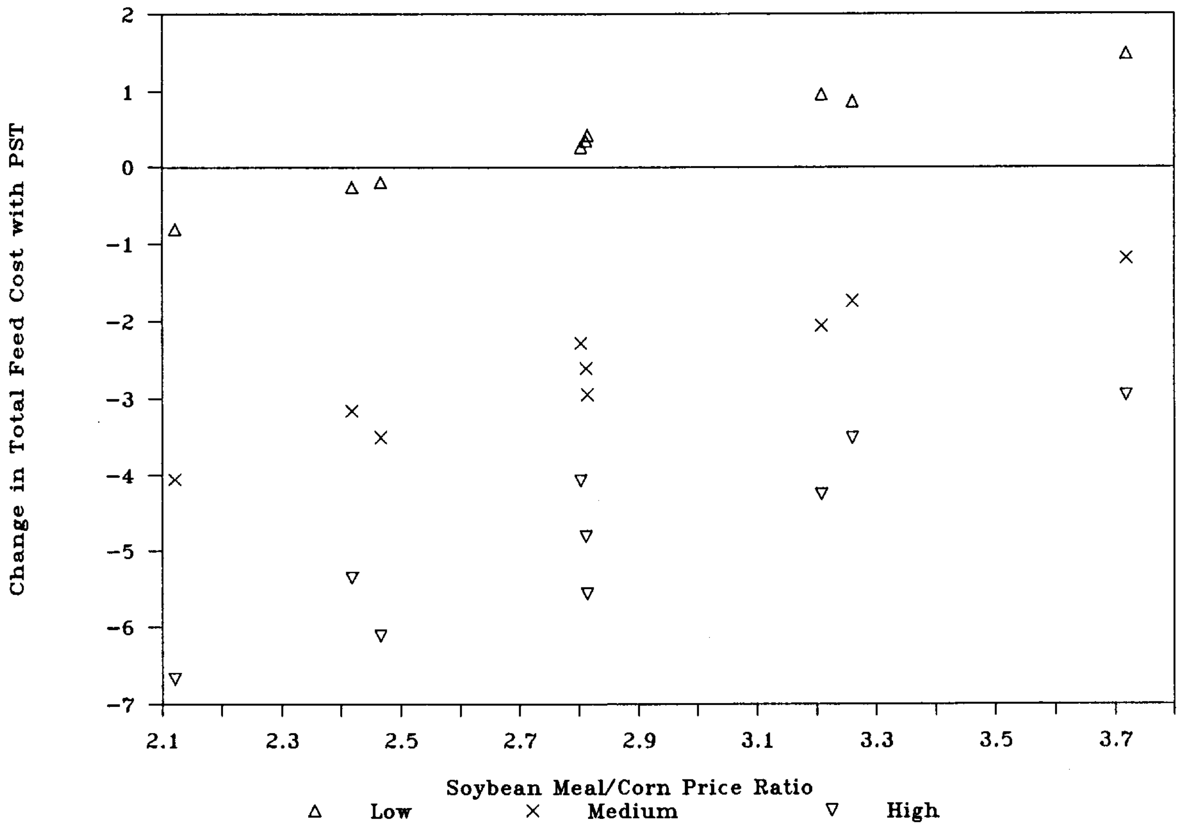

Figure 3: Change in Total Feed Cost Per Head for Each Rate of Response to Porcine Somatotropin as a Function of the Corn/Soybean Meal Price Ratio.

Summary and Conclusions

The impact of PST on swine feed costs is potentially great. At prices representative of recent market conditions, the reductions of feed cost per head associated with growth hormone use were found to be as high as 15.5 percent. At mean prices for corn and soybean meal and with an average response to PST, the savings in feed cost were about 6.4 percent. However, the published data indicate a wide range of responses to PST. At the low response rate considered here, feed costs declined with PST use only when the soybean meal/corn price ratio was low. And at the low response, feed costs increased 3.9 percent when the price of corn was low and the price of soybean meal high.

The wide range of impacts on feed costs suggest that with porcine somatotropin as with many new technologies, the risk perceptions of producers may play a significant role. The variability of responses indicated in the experimental data used here probably overstates the risk which producers will experience in commercial use of PST. However, the technical risk implied by PST use is an economic attribute which should be monitored in early commercial trials.

The benefits of PST, including those associated with feed costs, must be weighed against the cost of administering the growth hormone. The results here indicate that feed costs will decline less in the 170 to 230 pound range than at lower weights. However, it may be uneconomical to stop administering PST at the end of the feeding process because doing so would eliminate the effects of PST on carcass quality. It is also possible that upon withdrawal of PST, performance of the pigs would fall below that for pigs never receiving PST. The nature of administration costs will be important in determining the optimal timing of PST administration. If long term implant technologies are feasible, the marginal cost of having a longer administration period may be quite low. However, if additional implants are required to extend the period of administration, it may be uneconomical to do so.

In addition to the feed cost effects which were the focus of this study, the reduced time on feed for a given market weight or the increased market weight for a given time on feed implies savings on facilities costs and interest expense. Other benefits attributable to PST could come in the form of increased market prices due to the increased leanness of the meat. Detailed market level analyses will be needed to determine how wide scale use of PST will affect the supply and demand for pork and the prices received by producers. Similarly, further study is needed to determine the impacts of PST use on feed markets. The price of protein supplement relative to grain was found to be critical in determining the effects of PST on feed cost, suggesting that producers may be motivated to consider the substitution of alternative protein sources for soybean meal.

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