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Do Antibiotics Reduce Production Risk for U.S. Pork Producers?

Xuanli Liu, Gay Y. Miller, and Paul E. McNamara

We combine econometric and financial analyses of the NAHMS 2000 Swine Survey data to examine whether evidence exists for reducing risk by using antibiotics for growth promotion (AGP) in the U.S. swine industry. A stochastic dominance analysis of alternative lengths of time (days) of AGP application reveals that AGP used in the range of 65–75 days is preferred by risk-averse producers. Risk is reduced and profits are increased from use of AGP. The combined impacts of increased average daily gain and decreased variability in pig live weight increase producer profits by $2.99 per pig marketed.

Key Words: antibiotics, growth promotion, pigs, risk, stochastic dominance, variability

JEL Classifications: D21, D61, D81, Q12, R32

Production risk from weight variation of market pigs is an important concern in U.S. swine production. Packers' concern about carcass size variation arises partly because of process automation in slaughtering and partly because of the desire to provide consumers with consistently-sized cuts. Swine producers also care about weight variation because nonuniformity of weight results in price penalties for pigs marketed at weights outside defined standard weight intervals. Standard-sized market pigs reflect the needs and desires of swine producers, packers, and consumers.

Risk mitigation has been investigated in the context of some marketing mechanisms, including insurance, futures markets, and production contracts (Kliebenstein and Lawrence; Lapan and Moschini). Though used extensively, these risk reduction methods are not effective in dealing with the production risk from variation in pig weight. In fact, some commonly used mechanisms such as contracts with packers may increase the production risk from weight variability because of the requirements for shipment of pigs on specific dates. Input management may provide an efficient alternative for controlling the production risk arising from weight variation. An example of such an input management is the application of antibiotics for growth promotion (AGP) in swine production. Although this hypothesis has not been tested previously in the literature on pork production (to our knowledge), AGP may decrease variation in pig weight and hence lead to an increase in the revenue received at the farm level. If this hypothesis is true, it would imply that AGP would be valued by producers not only from their direct contribution to enhanced farm productivity through greater average daily gain (ADG), but also through risk reduction.

The impacts from the use of AGP on ADG

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and feed conversion ratio (FCR) have been examined in many studies (Cromwell; Hayes et al.; Hays; Losinger; Miller et al. 2003; Zimmerman). These studies focused on ADG and FCR, and found that use of AGP was associated with improved ADG and FCR of market hogs. Miller et al. (2004) found that use of AGP decreased stunted rate in market pigs and therefore may decrease variability in live weight of market hogs, but they did not evaluate the full influence of use of AGP on growth variability. Using data from Sweden, Hayes et al. addressed what might happen in the United States after removal of antibiotics. They modeled the sort loss and economic performance of the U.S. swine industry, assuming that the results obtained in Sweden would be similar in the United States. However, they did not fully examine the impacts of sort losses and did not estimate productivity parameters based on U.S. data. We extend the earlier work on the production impact of AGP in swine feeds by examining the change in risk associated with AGP and the choices of U.S. swine producers in the face of this changed risk.

The objectives of our study are to clarify the relationship between weight variation of market hogs and AGP, and to demonstrate the impacts of production risk, i.e., weight variation, on the AGP application decisions of swine producers. We develop econometric models to establish the relationship between AGP and production risk. A stochastic farm budget model is used to generate profit distributions under different AGP use. Finally, we model the decision-making of swine producers within the framework of stochastic dominance.

Theoretical Framework

Production risk represents an important dimension of livestock production (Anderson, Dillon, and Hardaker; Just). A risk-averse producer receives less utility from an average of risky returns than from its certainty equivalent. The choice of a risk-averse decision-maker could be quite different under conditions of uncertainty. We define and analyze production risk in this study as that risk derived from variability in the live market weight of pigs.

In swine production, production risk can be partially controlled by input management. Dillon distinguished predetermined, controllable, and uncontrollable inputs in livestock production. Controllable inputs such as rations, AGP, and bio-security are determined by swine producers. Predetermined inputs are those that are known but usually determined before the beginning of a production stage, outside of the swine production system, or outside of the direct control of a swine producer. Predetermined inputs may include inputs such as major facilities, the genetics of pigs, geographic location of the farm, and some environmental factors. Uncontrollable inputs may be known to swine producers at the time of decision-making, but their occurrence is not controllable. Uncontrollable inputs may include weather and possibly prevalence of specific disease pathogens.

Pork producers face substantial production risk from many and varied sources. Production risk sources may result from controllable, uncontrollable, and predetermined inputs. Production risk cannot be eliminated, but it can be reduced, in part, by managing controllable inputs.

There are risks for pork producers other than production risk. The change in live weight price experienced from 1995 to 1999 (from $30.3 to $52.9 of annual average for one hundred pounds) (USDA 2003) is a typical example of price risk in the pork industry. Daily or monthly prices paid to farmers would exhibit even more variability than implied by examination of annual average prices. Price risk may result from factors other than production yield variability. For example, unanticipated price swings might occur as a result of a demand shock from a pork substitute, e.g., the discovery of bovine spongiform encephalopathy in the U.S. beef supply. Swine producers also face other risks, such as institutional risk from changes in regulations, personal risk from life crises, and financial risk associated with leverage (Gollier and Pratt; Hardaker, Huirne and Anderson). Our study focuses on the impact of only production risk, although other risk may be of substantial empirical importance to overall hog farm profits.

Swine producer profits from a barn of pigs under conditions of production risk are expressed as:

$$(1)\quad h(\pi \mid x_1x_2 \cdots x_g) = h\left\{\left[\sum_{i=1}^{n} p(y_i)y_i - \sum_{j=1}^{k} c_jx_j - C\right] \middle| x_1x_2 \cdots x_g\right\}$$

where $p(y_i)$ is the price for a market hog i, y_i is the weight of the market hog i, n is the number of pigs in a barn, c_j is the cost for input j, x_j is input j, C is fixed costs, $x_1, \ldots, x_g$ is a set of controllable inputs that affects variability in production yield, and $h(\pi)$ represents the density function of the profit distribution conditional on variability of production yields that is related to the controllable input set. We assume, for simplicity, that all costs not related to controllable inputs are fixed.

Decision-making of farmers under conditions of uncertainty is traditionally modeled by expected utility or stochastic dominance analysis (SDA). Expected utility analysis poses difficulties in application because of the essential requirement of eliciting a utility function. SDA, in comparison, places fewer restrictions on behavior of farmers and represents a more robust alternative for the analysis of decision-making under risks (Dillon; Hardaker, Huirne, and Anderson; Meyer).

In this study, we model the decision-making of swine producers by SDA, where we include first-, second-, and third-order stochastic dominance, abbreviated by FSD, SSD, and TSD, respectively. We define the cumulative density function (CDF) for a density function $h(\pi)$ as

$$D_h^1(\pi) = \int_a^{\pi} h(r)\, dr,$$

$$D_h^2(\pi) = \int_a^{\pi} D_h^1(r)\, dr, \quad \text{and}$$

$$D_h^s(\pi) = \int_a^{\pi} D_h^{s-1}(r)\, dr.$$

If $D_{h_1}^1(\pi) \leq D_{h_2}^1(\pi)$ for all values of $\pi \in [a, b]$ and $D_{h_1}^1(\pi) < D_{h_2}^1(\pi)$ for at least one value of π, the probability density function h_1 is FSD dominant to another probability density function h_2. FSD can characterize the behavior of decision-makers who prefer more profits to less, but fails to find a dominance relationship if the CDFs of alternatives cross. SSD has more discriminatory power. A probability distribution h_1 dominates another probability distribution h_2 by SSD if $D_{h_1}^2(\pi) \leq D_{h_2}^2(\pi)$ for all values of $\pi \in [a, b]$ and $D_{h_1}^2(\pi) < D_{h_2}^2(\pi)$ for at least one value of π. A dominant relationship under SSD means that decision-makers prefer not only more profits, but also less risk for all values of $\pi \in [a, b]$. In the absence of FSD and SSD, TSD may be identified if the coefficient of absolute risk aversion is decreasing with wealth (Dillon). A probability distribution h_1 dominates another distribution h_2 by TSD if SSD holds between the two, $D_{h_1}^3(\pi) \leq D_{h_2}^3(\pi)$ for all values of π, and $D_{h_1}^3(\pi) < D_{h_2}^3(\pi)$ for at least one value of π.

We conducted SDA for 13 profit distributions derived from the results of simulations. Our SDA follows the methods and program in Sahn and Stifel. We test 20 null hypotheses H_0: $D_{h_1}^s(\pi) - D_{h_2}^s(\pi) = 0$ to identify the existence of the sth-order dominance between two distributions.

Data

The majority of data in this study are from the three swine surveys conducted in 2000 by the USDA's National Animal Health Monitoring System (NAHMS). The initial survey was of 2,333 swine producers in the 17 major pork-producing states. These 17 states accounted for 94% of the U.S. pig inventory and 92% of U.S. pork producers with 100 or more pigs in inventory (USDA NAHMS). Additional conducted surveys of subsets of the original 2,333 producers provided additional data on productivity measurements, managerial factors, rations, bio-security, and the use of antibiotics.

Information on AGP, a crucial set of inputs in our study, was gathered and well documented in the NAHMS survey. Producers provided information for each of 26 antibiotics used in feed. The data include the primary reasons for antibiotic use, antibiotic dose per day, and total days in the feed. Six primary reasons for using antibiotics were growth promotion, general disease prevention, respiratory disease treatment, enteric disease treatment, parasitic treatment, and other treatments. A summation of different antibiotics used in feed provided the number of different AGP. Similarly, a summation across the corresponding days in feed gave the total days AGP are fed.

We derived live weight and variability of live weight for grow/finish pigs for each farm from NAHMS 2000 survey data and PigCHAMP® 1999 data. We estimated weight added during the growing/finishing stage based on farm-level averages of entry age, market age, and ADG of pigs from NAHMS 2000 data. We estimated average entry weight at varying ages from PigCHAMP® 1999 data. The two estimates led us to the estimated live weight of market hogs for each farm.

The variability in live weight of market hogs was estimated in two steps. First, the swine farms were classified into 32 categories according to AGP in terms of total number of days antibiotics were fed (Table 1). Second, the variability (standard deviation) in live weight of market hogs was calculated for each AGP category. The standard deviation estimated for each AGP category is not necessarily the actual standard deviation of live market weight of pigs within individual swine farms; rather, it reflects variability in estimated live weight between farms. Nevertheless, in view of the general unavailability of the data, the standard deviations estimated here represent an empirical approximation and possibly give lower bound estimates of the live weight standard deviations on swine farms.

Two econometric models are estimated. The first model establishes the relationship between ADG and inputs such as AGP and other factors. The ADG model is estimated by ordinary least squares (OLS). The initial variable selection in the process of modeling ADG is based on production practices, and confined to the data available in the NAHMS 2000 Swine Survey. We retain those variables with $P \leq 0.15$ and exclude other variables. The model fitted is presented in Table 2.

Table 1. Live Weight Mean, Variability and AGP[a]

Ranking groups	Number of Farms	Day of AGP	Mean Live Weight	Estimated SD in Live Weight
1	115	0	243.47	30.68
2	6	9	263.90	20.86
3	6	19	247.08	48.25
4	6	25	225.14	35.79
5	6	30	254.47	10.20
6	6	34	248.25	30.12
7	6	40	249.02	38.91
8	6	43	230.01	24.84
9	6	49	257.28	16.53
10	6	50	249.46	4.32
11	6	57	228.63	19.81
12	6	60	241.59	17.68
13	6	63	228.95	26.16
14	6	70	252.97	16.64
15	6	72	246.82	29.21
16	6	79	228.74	23.75
17	6	80	241.46	19.60
18	6	87	227.91	16.24
19	6	90	236.34	25.48
20	6	95	251.26	24.16
21	6	100	250.67	29.65
22	6	100	238.39	17.96
23	6	100	239.84	44.05
24	6	102	253.36	4.55
25	6	109	256.57	31.86
26	6	111	258.84	43.91
27	6	117	242.69	17.87
28	6	120	237.95	22.46
29	6	120	254.35	9.36
30	6	124	238.22	26.62
31	6	143	277.63	63.13
32	7	159	252.28	23.66

[a] AGP = Antibiotics used for growth promotion.

The second model establishes the relationship between production risk (variability of live market weight) and AGP using weight OLS. The dependent variable is the standard deviation of live market weights. Independent variables are the days AGP are fed, and this term squared. The data are from 32 categories of AGP (Table 1).

Price and cost data were used to estimate

Table 2. Variables Associated with Average Daily Gain in the Grow/Finish Stage[a]

Variable	Description	Parameter Estimate	Standard Error	*P*-value
Intercept		1.651	0.029	.0001
AGP	Number of days antibiotics used for growth promotion	0.002	0.001	.040
$(AGP)^2$	Square of number of days antibiotics used for growth promotion	−1.1E−05	0.7E−05	.116
Off-site2	Percentage of pigs from other site	−0.078	0.054	.140
DeathreasonNum	Number of reasons given for pig death in the G/F stage	−0.010	0.006	.106
Dration5_up	Using 5 or more different rations	0.043	0.020	.029
Northern	Northern region (Michigan, Minnesota, Pennsylvania and Wisconsin)	0.055	0.024	.024

[a] *P*-value of *F*-statistic for AGP and AGP^2 jointly is .014; Model $R^2 = 0.08$.

profit distributions using a farm-level stochastic budget model. In the hog market, prices paid to producers by a packer are different for standard-weight pigs and nonstandard-weight pigs (Miller, Song, and Bahnson). Also, price matrices differ across packers (Boland; Miller, Song, and Bahnson; USDA 1995). We use the same pricing matrix as Miller, Song, and Bahnson in a stochastic budget model, where pig prices depend on pig weights, above and below a 50-lb. live weight range (230–280 lbs. = base price range). Price penalties were imposed on pigs of nonstandard size (Table 3). The base price ($42/100 lbs. live weight) for standard-weight pigs is based on the average of annual USDA data from 1995 to 1999 (USDA 2003).

Table 3. Price Matrix of Market Weight Hogs[a]

Live Weight Class	Price Penalty ($/cwt)
<190	7
191–201	7
201–211	5
211–221	3
221–230	1
230–241[b]	0
241–251[b]	0
251–261[b]	0
261–271[b]	0
271–281[b]	0
281–291	0.5
291–301	1.5
301–311	2.5
311–321	4.5
320<	6.5

[a] Source: Miller et al. (2001).
[b] Base price received assumed = $42; this weight range receives the highest price.

Production costs per 100 lbs. of live market weight from 1995 to 1999 were from USDA (2000). The costs included feed ($17.96/100 lbs. live weight), operating costs ($17.97/100 lbs. live weight), and overhead ($6.25/100 lbs. live weight). The costs of antibiotics were treated separately. We used Cromwell to calculate antibiotic costs, and estimated the costs of antibiotics to be $0.0042 per pig per day.

Associations between AGP and Market Weights

Two econometric models were established to provide estimates of the association between: 1) AGP and mean live market weight, and 2) AGP and standard deviation of live market weight. A perusal of the NAHMS data collection forms reveals that there are many possible variables available in the NAHMS data set. We initially selected a set of variables that might be relevant to determining ADG. Those variables included farm scale, type of farm management system, facilities used in production, waste management, number of veterinary consultations, number and type of rations used in production, biosecurity measures, three re-

Table 4. Association between Variability in Live Market Weight in the Grow/Finish Stage and Number of Days Antibiotics Used for Growth Promotion[a]

Variable	Description	Parameter Estimate	Standard Error	P value
Intercept		31.018	2.680	0.0001
AGP	Number of days antibiotics used for growth promotion	−0.257	0.116	0.033
$(AGP)^2$	Square of number of days antibiotics used for growth promotion	0.002	0.001	0.048

[a] P value of F statistic for AGP and AGP^2 is 0.08; Model $R^2 = 0.15$; this model is based on data from Table 1.

gional dummy variables, AGP use, and antibiotics used for disease prevention. We chose variables to investigate based on our understanding of the impact on ADG from our knowledge of pork production, and retained variables based on a set of criteria for model selection (variance inflation factor [*VIF*]), R^2, C_p, and p value). We did not use a stepwise regression procedure. Rather, we used a subset of methods and retained variables in the model based on various specific criteria. Values of *VIF* for all variables retained were less than 10. Values for C_p were close to the potential number of explanatory variables for all variables retained. We used these two criteria because the *VIF* measures the degree of variance increase if there is collinearity; the C_p criterion was used to avoid the model being over- or underspecified. Most variables available from the NAHMS survey were not included in the model because they were not appropriate for explaining ADG or because of lack of power (the impact on reducing the mean-squared error) in explaining ADG. Following these procedures, we identified five important variables associated with ADG in the grow/finish stage (Table 2). The number of days AGP is fed, the proportion of pigs obtained from an off-site source, the number of reasons given for pig deaths, the use of five or more different rations, and the Northern United States production region were all significant factors. The second model identifies that the use of AGP was associated with the standard deviation of live market weights (Table 4). The t-statistics for both AGP and AGP^2 reveal a significant association ($P < 0.05$) and the F-test for AGP and AGP^2 jointly suggests a significant association ($P < 0.10$).

Limited by the sample size (32 observations), and the need to estimate as best as possible the standard deviation within AGP categories, we did not include other variables in the model. This may lead to estimates associated with: (1) p values (0.033 for AGP and 0.048 for AGP^2) for individual t-statistics that understate the possibility of a type 1 error because the sampling variability of parameters from a subset model will be equal to or less than the sampling variability of parameters from a fully specified model with all relevant variables retained; and (2) a p value (0.08 for AGP and AGP^2 jointly) for the F-test that overstates the possibility of a type 1 error for AGP and AGP^2 jointly because a subset model usually overestimates mean squared error (MSE) (Hocking; Judge et al.; Wallace). The two results imply a true p value for AGP and AGP^2 jointly in the range of 0.03 to 0.08, which suggests a reasonable model fit given the sample limitations. The ADG and SD models expressed in fitted equation form are:

$$(2)\quad \begin{aligned} \text{ADG} = {} & 1.65 + 0.0017\text{AGP} \\ & - 0.000011(\text{AGP})^2 - 0.78\text{Off-site2} \\ & - 0.01\text{DeathreasonNum} \\ & + 0.043\text{Dration5\_up} \\ & + 0.055\text{Northern} \end{aligned}$$

$$(3)\quad \text{SD} = 31.02 - 0.257\text{AGP} + 0.002(\text{AGP})^2.$$

The first derivative of ADG with respect to AGP shows that ADG reaches a maximum

Table 5. Mean Live Weight and the Standard Deviation Predicated from Fitted Equations[a]

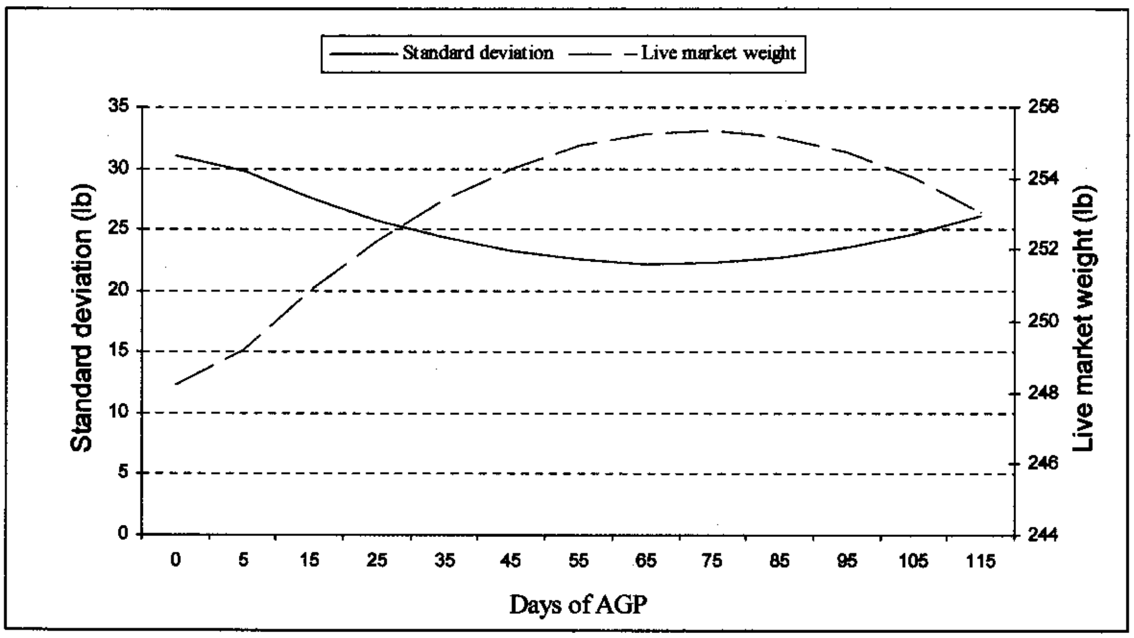
Days of AGP	SD	Mean Live Weight
0.00	31.02	248.24
5.00	29.78	249.18
15.00	27.58	250.85
25.00	25.76	252.26
35.00	24.31	253.40
45.00	23.23	254.28
55.00	22.53	254.90
65.00	22.20	255.25
75.00	22.25	255.34
85.00	22.67	255.16
95.00	23.46	254.72
105.00	24.63	254.01
115.00	26.17	253.04

[a] Fitted equations are based on results from Tables 2 and 4. These equations are: $ADG = 1.65 + 0.0017AGP - 0.000011(AGP)^2 - 0.78\text{Off-site2} - 0.01\text{DeathreasonNum} + 0.043\text{Dration5\_up} + 0.055\text{Northern}$; $SD = 31.018 - 0.257AGP + 0.002(AGP)^2$.

(negative second derivative) when AGP is equal to 77 days of feeding. Equivalently stated, when the average farmer uses AGP for 77 days, pigs will reach a specific weight in the least number of days on feed (because ADG is at a maximum), or equivalently, pigs will get to the heaviest possible weights in a specific number of days when AGP use is equal to 77 days. A similar calculation finds that the SD of live market weight reaches the minimum (positive second derivative) when pigs were fed AGP for 64 days.

Fitted results implied by the two models (live marketing weight and live market weight variability under different scenarios of subtherapeutic use of AGP) are reported in Table 5. A graphical presentation of the data from Table 5 is presented in Figure 1.

Our results (Tables 2 and 4) show that both ADG and variation in live market weight for pigs in the grow/finish stage are related to the use of AGP. Significant quadratic terms in both models illustrate the nonlinearity of the impact from AGP. By using fitted data (Table 5) and the corresponding graphical presenta-



Note: The curves of standard deviation and live market weights are from data in table 5.

Figure 1. Variability and Mean of Live Market Weight with Varying Days of AGP (Antibiotics for Growth Promotion)

Table 6. Profits per Pig for Varying AGP[a]

Days of AGP[a]	Profit Per Pig			
	Mean		SD	
	Combined Impacts[b]	Mean Impact[c]	Combined Impacts[b]	Mean Impact[c]
0	−4.26	−1.56	4.57	4.75
5	−3.82	−1.35	4.33	4.75
15	−3.05	−0.98	3.88	4.75
25	−2.42	−0.69	3.47	4.75
35	−1.94	−0.46	3.14	4.75
45	−1.59	−0.28	2.88	4.75
55	−1.37	−0.17	2.71	4.75
65	−1.27	−0.13	2.64	4.75
75	−1.29	−0.14	2.65	4.75
85	−1.43	−0.22	2.74	4.75
95	−1.69	−0.34	2.93	4.75
105	−2.08	−0.54	3.21	4.75
115	−2.60	−0.79	3.56	4.75

[a] AGP = Antibiotics used for growth promotion.
[b] Combined impacts include changes in expected live weight and live weight variability under varying levels of antibiotic use.
[c] Mean impact includes only the impact of changes in mean live weight.

tion (Figure 1), we see that use of AGP is associated with increases in live market weight at a decreasing rate, up to 77 days of use, and then is associated with declines in ADG. AGP also is associated with decreases in variation in live market weight at a decreasing rate, up to 64 days of use, and then is associated with increases in variation in live market weight.

Association between Producers' Profits and AGP

Producers' profits from market hogs fed AGP for varying days were established from the stochastic budget model. We assumed a normal distribution (with the first two moments from Table 5) of the live weight for a market pig; we generated 5,000 pig weight observations for each distribution corresponding to each AGP category through Monte Carlo simulation. We then applied the pricing matrix to the generated set of weights to derive producers' profits using Equation (1). In the calculation, we assumed swine producers did not face any market-side risk. The variability in producers' profits, therefore, resulted only from variation in pig live weight.

Two sets of 13 profit distributions were estimated from the stochastic budget model (Table 6). One set of profit distributions used the combined impacts of mean weight and weight variation. The other set of estimates reflected the influence of mean weight only. In the case of combined mean and variation effects, when swine producers do not use AGP, they are exposed to an average loss of $4.26 per market pig and a more volatile profit (SD = 4.57). However, when swine producers use AGP for a little more than two months, loss is reduced from $4.26 to $1.27 per pig, and the standard deviation decreases from 4.57 to 2.64. The increase of $2.99 in profits per pig consists of $1.43 from an increase in mean weight and $1.56 from a decrease in variation in live market weight of pigs. Thus, weight variation is a more important influence on profits than is mean weight. Expected profits are highest and variability of profits is lowest with AGP applied in the range of 65–75 days.

Stochastic Dominance Results

One set of 13 profit distributions, which combines mean and variation effects, are compared and ranked with SSD. The results of pairwise dominance comparisons are reported in Table 7, where no SD of any order is shown with a zero, SSD is represented with a two, and TSD is represented with a three. No stochastic dominance of any order occurred between adjacent pairs of distributions. However, two distributions, 65 and 75 days of AGP use, are SSD dominant to most other distributions, except for their adjacencies. The existence of SSD suggests that risk-averse swine producers are likely to pursue a strategy of AGP use rather than no AGP in their production and may prefer AGP use in the 65–75 day range.

Although FSD is not observed, the comparison of the profit distribution from 65 days of AGP with the distribution from no AGP indicates a relationship that is approximately FSD. Among 20 pairwise comparison tests of FSD between two distributions with 65 days

Table 7. Dominance Relationships between Various AGP Scenarios

	AGP Scenario												
	1[a]	2	3	4	5	6	7	8	9	10	11	12	13
1	0[b]												
2	0	0											
3	0	0	0										
4	3[d]	0	0	0									
5	2[c]	3	0	0	0								
6	2	2	3	0	0	0							
7	2	2	3	0	0	0	0						
8	2	2	2	3	0	0	0	0					
9	2	2	2	3	0	0	0	0	0				
10	2	2	3	0	0	0	0	0	0	0			
11	2	2	3	0	0	0	0	0	0	0	0		
12	2	2	0	0	0	0	0	0	0	0	0	0	
13	3	3	0	0	0	0	3	3	3	0	0	0	0

[a] Each scenario is a pairwise comparison of days of AGP from Table 6.
[b] 0 means no SD of any order.
[c] 3 means the row scenario TSD the column scenario.
[d] 2 means the row scenario SSD the column scenario.

of AGP and no AGP, only one comparison test had $P > 0.05$. The graphic presentation (Figure 2) with three profit distributions further confirms the test results. This suggests that producers, no matter their risk preference, would prefer AGP use.

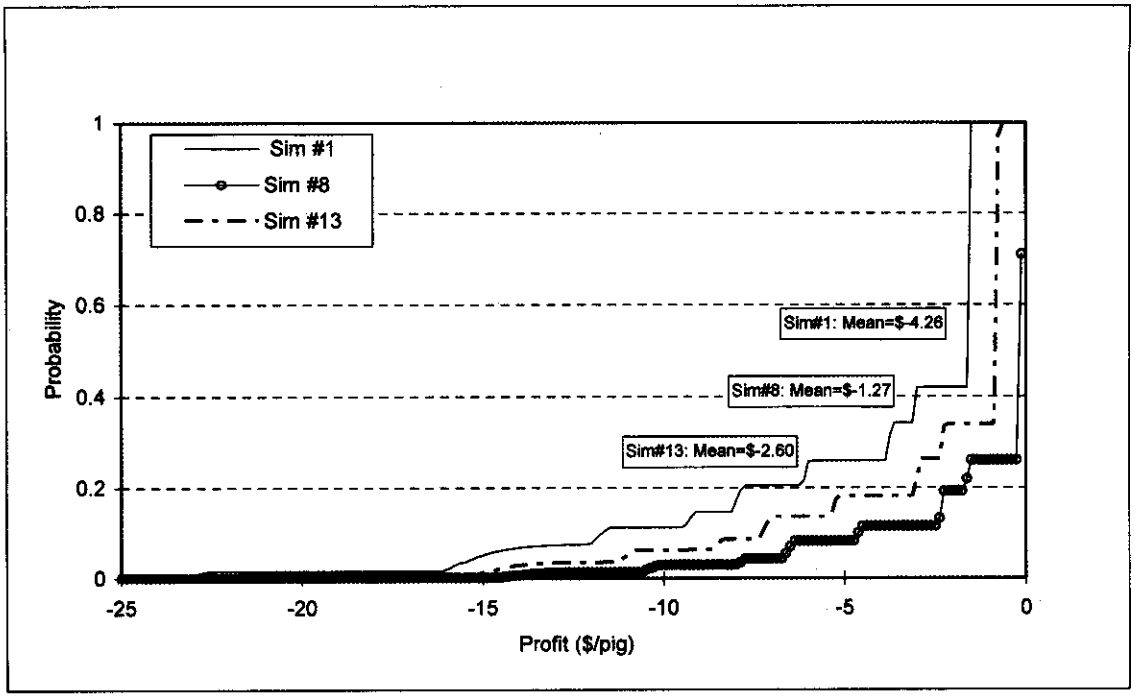
Swine producers may also prefer use of AGP in the 65–75 day range because of the high benefit-cost ratio of AGP. Based on Cromwell (2001), the costs of AGP are estimated to be $0.0042 per pig per day. If producers use AGP for 65 days, the cost incurred is about $0.27 for a pig in the grow/finish stage, which is very small compared with the total production costs of $106 per pig. However, this small cost is associated with a substantial increase in profits. The increase in ADG associated with AGP use will generate on average $1.43 in extra profits per pig for swine farmers. The combined impacts of the increased ADG and decreased variability in pig live weight will provide producers extra profits of $2.99 per pig on average. Thus, the benefit-cost ratio associated with AGP use of 65 days is 11.1 (2.99/0.27). The high benefit-cost ratio is another possible explanation for why 63% (Miller et al. 2004) of swine producers currently use AGP.

Limitations of Our Analysis

As a first attempt to measure the risk-reducing role of AGP, our analysis has a number of limitations. First, we derive the weight variation measures from subgroups of producers categorized by days of AGP use. This estimate may not accurately reflect the standard deviation in live market weight actually experienced at the farm level. However, we believe our estimate is the best that could be achieved given the data limitations we faced.

Second, swine producers sometimes reduce the proportion of lightweight market pigs by extending the days to slaughter in the grow/finish stage or by marketing pigs anticipated to be slow growers as roasted pigs early in the grow/finish stage (Song and Miller). Producers may face less variation than we assumed because of such marketing strategies. However, there is trade-off between reducing weight variation and the costs for extending time to slaughter.

Third, ADG, entry age, and marketing age in NAHMS 2000 data were used to estimate live market weight. Data quality and bias are also possible when observations are excluded because of missing data. There is some poten-



Note: Profits from simulation (Sim) 1, 8 and 13 present distributions with 0, 65 and 115 days of AGP.

Figure 2. Profits with Varying Days of AGP (Antibiotics for Growth Promotion)

tial bias from missing data, at least with regard to farm size. Larger farms are more represented in the data used for analysis than in the entire dataset (Miller et al. 2004).

Fourth, the relationship that might exist between AGP and market prices is not examined in this study. For example, we do not consider the issue of niche pork markets, which target consumers' demand for AGP-free pork and might command a higher market price.

Conclusions

In this paper, we have presented a quantitative analysis of the reduction in production risk that is associated with AGP use in pork production.

Changes in producers' profits are likely realized from the association of AGP use with mean live weight and weight variation. The change in weight variation is a more important influence on profits than the influence of mean weight. Expected profits are highest and variability of profits is lowest with AGP applied in the range of 65–75 days. This range incorporates the mean AGP of 72 days currently used by producers. The degree of risk aversion has limited effect on the use of AGP; risk-averse producers behave similarly in their AGP choices to risk neutral producers. In addition, the high benefit-cost ratio for AGP may be another driving force of the extensive use of AGP.

Swine producers in the United States have strong incentives to use AGP. The incentives include improved pig growth performance, reduced production risk, and improved profits. Producers may have additional incentives not examined in this study, including the influence that AGP might have on decreasing swine diseases and enhancing overall swine health and any other direct and indirect influences that might change prices or total revenues received by producers or costs of production.

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References

Anderson, J.R., J.L. Dillon, and J.B. Hardaker. *Agricultural Decision Analysis*. Ames, IA: Iowa State University Press, 1977.

Boland, M.A. "Economic Optimization of Animal Replacement, Ration Composition, and Nutrient Management: An Application to Pork Production." Ph.D. dissertation, Purdue University, 1996.

Cromwell, G.L. "Why and How Antibiotics Are Used in Swine Production." *Animal Biotechnology* 13(2002):7–27.

Dillon, J.L. *The Analysis of Response in Crop and Livestock Production*. Oxford: Pergamon Press, 1977.

Gollier, C. and J.W. Pratt. "Risk Vulnerability and the Tempering Effect of Background Risk." *Econometrica* 64(1996):1109–23.

Hardaker, J.B., R.B.M. Huirne, and J.R. Anderson. *Coping with Risk in Agriculture*. New York: CAB International, 1997.

Hayes, D.J., H.H. Jensen, L. Backstrom, and J.F. Fabiosa. "Economic Impact of a Ban on the Use of Over-the-Counter Antibiotics in U.S. Swine Rations." *International Food and Agribusiness Management Review* 4(2001):81–97.

Hays, V.W. *Effectiveness of Feed Additive Usage of Antibacterial Agents in Swine and Poultry Production*. Office of Technology Assessment, U.S. Congress, Washington, DC, 1977.

Hocking, R.R. "The Analysis and Selection of Variables in Linear Regression." *Biometrics*, 32(1976):1–49.

Judge, G. G., W. E. Griffiths, R. C. Hill, and T.C. Lee. *The Theory and Practice of Econometrics*. New York: John Wiley & Sons, 1980.

Just, R.E. "Risk Aversion under Profit Maximization." *American Journal of Agricultural Economics* 57 (1975):347–52.

Kliebenstein, J.B., and J.D. Lawrence. "Contracting and Vertical Coordination in the United States Pork Industry." Staff Paper No. 265, Iowa State University, Department of Economics, 1995.

Lapan, H., and G. Moschini. "Futures Hedging under Price, Basis, and Production Risk." *American Journal of Agricultural Economics* 76,3(1994):465–77.

Losinger, W.C. "Feed-Conversion Ratio of Finisher Pigs in the USA." *Preview of Veterinary Medicine* 36(1998):287–305.

Meyer, J. "Two-Moment Decision Models and Expected Utility Maximization." *American Economic Review*, 77(1987):421–30.

Miller, G.Y., Y. Song, and P.B. Bahnson. "An Economic Model for Estimating Batch Finishing System Profitability with an Application in Estimating the Impact of Preventive Measures for Porcine Respiratory Disease Complex." *Journal of Swine Health and Production* 9(2001): 169–77.

Miller, G.Y., K.A. Algozin, P.E. McNamara and E.J. Bush. "Productivity and Economic Impacts of Feedgrade Antibiotic Use in Pork Production." *Journal of Agricultural and Applied Economics* 12(2003):469–82.

Miller, G.Y., X. Liu, P.E. McNamara and E.J. Bush. "Producer incentives for antibiotic use in U.S. pork production." *Journal of Agribusiness*, 23(2005):147–162.

PigCHAMP®. *Benchmarking in Swine Herds*. Regents of the University of Minnesota, p. 90. 1999.

Sahn, D.E., and D.C. Stifel. "Robust Comparisons of Malnutrition in Developing Countries." *American Journal of Agricultural Economics*, 84(2002):716–35.

Song, Y.H., and G.Y. Miller. "Effects of Marketing Decisions on Net Present Value of Pork Production for Independent and Allied Swine Producers." *Review of Agricultural Economics*, 24,1(Spring/Summer 2002):181–95.

U.S. Department of Agriculture. *Livestock, Meat, and Wool Weekly Summary and Statistics*. Livestock and Seed Division, Agricultural Marketing Service, United States Department of Agriculture, January–December 1995.

———. *Hog Costs and Return Data*. Economic Research Service, United States Department of Agriculture, September, 2000. Internet site: http://ers.usda.gov/data/FarmIncome/car/hogs3.htm (Accessed May 13, 2003).

———. *Agricultural Statistics 2003*. National Agricultural Statistics Service, 2003. Internet site: http://www.usda.gov/nass/pubs/agr03/acro03.htm (Accessed August 15, 2003).

U.S. Department of Agriculture, National Animal Health Monitoring System. Part 1: Reference of Swine Health and Management in the United States, 2000, August 2001.

Wallace, T.D. "Pretest Estimation in Regression: A Survey." *American Journal of Agricultural Economics*, 59(1977):431–43.

Zimmerman, D.R. "Role of Subtherapeutic Levels of Antimicrobial in Pig Production." *Journal of Animal Science* 62(Suppl. 3, 1986):6–17.