Subtherapeutic Antibiotics and U.S. Broiler Production

James M. MacDonald and Sun-Ling Wang

Economic Research Service, U.S. Department of Agriculture

(contact: MacDonald at 202-694-5610, and macdonal@ers.usda.gov)

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Abstract

We use data from a recent national survey to analyze the use of subtherapeutic antibiotics (STAs) among producers of broilers. STAs are included in feed or water and are intended to prevent disease or promote growth. Producers who do not use STAs instead rely on a set of other practices, including pathogen testing, expanded sanitary protocols, altered feeding regimens, and HACCP plans, to maintain production. We find that producers who do not use STAs realize levels of production that are slightly lower, given other inputs, than STA users, but the differences are not statistically significant. STA users realize lower payments per pound than those who are not users. The 4 percent difference, which is statistically significant, suggests that STA users have lower costs.

Livestock producers use a variety of practices to prevent the emergence and spread of animal diseases among their herds and flocks. Such practices include pathogen testing, vaccinations, age and sex-specific feeding rations, segregation of herds or flocks by age, sanitary protocols in housing units, physical biosecurity measures, and the provision of antibiotics.

Antibiotics are widely used in modern livestock and poultry production to treat sick animals, but they are also administered in subtherapeutic doses, usually in water or feed, to protect animals against disease and to promote growth. Subtherapeutic antibiotics (STAs) can promote growth, particularly in poultry and hogs, by improving nutrient absorption and by depressing the growth of organisms that compete for nutrients, thereby increasing feed efficiency.

But there is growing concern among health officials, physicians, veterinarians, and the broader public about the diminishing efficacy of many antibiotics in treating human and animal diseases. In particular, the widespread use of antibiotics encourages the growth of antibiotic resistance in pathogen populations. In agriculture, increased resistance to animal antibiotics can lead to more severe outbreaks of disease among animal and poultry populations. Resistant bacteria may cause disease directly or they may pass genetic material associated with resistance on to other bacteria. Consequently, there is concern that the widespread use of antibiotics, including STAs in animals, could promote development of drug-resistant bacteria that could pass from animals to humans, thus posing a danger to human health. In response to these concerns, the European Union (EU) has banned the use of antimicrobial drugs for growth promotion, and they are coming under growing scrutiny in the U.S. (U.S. Government Accounting Office, 2008).

This paper assesses STA use in U.S. broiler production, relying on data from a recent large-scale representative survey of broiler producers. We summarize the extent of STA use on broiler operations; farms that do not use STAs instead rely on specific alternative practices, and we describe the steps that operations take to prevent diseases and promote growth in the absence of STAs. We then compare production outcomes at farms that do and do not use STAs. Because the comparison groups are not randomly selected—that is, farms that do not use STAs differ in some important respects from those that do—we also take account of selection into STA use in our comparisons of production outcomes.

Prior Work on STA Removal

We draw on two prior studies of STA removal in broiler operations. Emborg, et al. (2001), analyzed the impact of suspending STA use in poultry production in Denmark, where the use of antimicrobial growth promoters was discontinued in February of 1998. The study evaluated flock-level performance using a database developed by the Danish Poultry Council, an industry association, starting in the 1970's. Specifically, the analysis focused on flocks slaughtered between January 1996, and July, 1999, and evaluated feed conversion rates, mortality, and house capacity utilization before and after the suspension on February 15, 1998.

The Council's database included data from about 70 percent of Danish poultry farms, but adequate productivity data were available for less than half of the reported flocks. The analysis controlled for house and farm fixed effects, as well as production cycle data (weight or age). Emborg, et al., report that there was no significant change in mortality rates after the suspension, nor was there a significant change in capacity utilization (broiler production per square meter). There was a statistically significant increase in feed conversion (more feed per pound produced) after the suspension, but the increase was quite small—0.016, or 0.88 percent of the median feed conversion rate of 1.8 pounds of feed per liveweight pound produced.

The study had no data on how Danish operations changed their production practices after STAs were removed--the analyses only show how production outcomes changed within farms and houses. But there is some indication that producers were learning how to produce without STAs—feed conversion rates spiked just after the suspension, and then trended back towards pre-suspension values during the rest of the study period, and producers experimented with different feeds and production practices.

Engster, et al. (2002) reported on the results of a U.S. poultry company's three-year study of withdrawing growth-promoting antibiotics. The study used 158 paired houses in North Carolina (NC) and the Delmarva Peninsula (DMP). Trial and control houses were paired on the same farm, and each paired house was identical in size, technology, production practices, chick placements, and production cycle length. Results were compared for 10 different trials, each covering 3-4 month periods. Unfortunately, the article, which was published as part of an "Informal Symposium", did not report tests of statistical significance, but only reported differences in means.

Feed conversion rates were higher in the non-STA houses, in each trial period and in each location. The average difference, 0.016 in DMP and 0.012 in NC, was quite similar to that found in the Danish study (0.016 pounds of feed per pound of liveweight gain) and amounts to less than a one percent increase. The study also found slight differences in liveability (percent of chicks surviving). The non-STA flocks had slightly lower liveability, 0.2 percent lower in DMP and 0.14 percent lower in NC.[1]

Engster et al.'s results indicate that STAs were more effective at promoting growth and preventing disease in dirtier houses. In the first production cycle after houses were cleaned and new litter put down, non-STA houses had higher average liveability and lower feed conversion rates that houses where STAs were used. Performance in non-STA flocks only deteriorated, compared to STA flocks, during the second and third production cycles after a litter change—that is, when sanitary conditions were poorer. The results suggest that expanded sanitation practices may provide a substitute for STAs.

There have been several studies of STA use and removal on hog operations. Miller et al. (2003) provide a review of the early work on the effects of growth promoting antibiotics, and they use 1990-95 data collected as part of the National Animal Health Monitoring System (NAHMS) to assess the links between the use of growth-promoting

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[1] Graham, et al. (2007), used the Engster, at al., data to argue that the expense of antibiotics exceeded the value associated with the modest gains in liveability, average daily gain, and feed conversion. However, they appear to have valued the increased production according to the fees per pound paid to growers, instead of the much higher value per pound to the integrator, and hence understated benefits.

antibiotics and on-farm productivity. They compare production outcomes among farms that used growth-promoting antibiotics to farms that didn't; as in the two poultry studies, they found that STAs were associated with small production gains. On average, those farms using antibiotics had a lower feed conversion rate (1.1 percent), lower mortality rate (0.22 percentage points), and higher rate of average daily gain (0.5 percent).

Given the expenses associated with antibiotics and the additional revenue to be gained from increased production, Miller et al, estimated that antibiotics added 59 cents per head to the operation's profitability. However, they also found that the effects of antibiotics were conditional on other factors—specifically, they were less effective on operations that tailored rations to the age of the hogs being fed. More generally, they argued that antibiotics were a simple substitute for alternative practices aimed at promoting growth and deterring disease.

The study that is most closely related to ours is that by McBride, et al (2008), who used farm-level data from the same USDA survey that we rely on.[2] Producers were asked whether they provided antibiotics, the purpose for provision (growth promotion, disease prevention, or disease treatment), and the types of animals receiving the drugs (breeding animals, nursery pigs, or finishing hogs). Antibiotics were used most widely on nursery pigs in specialized wean-to-feeder operations: 80 percent of the surveyed farms used antibiotics for disease treatment, and 85 percent provided STAs for either disease prevention or growth promotion.

[2] We describe the data in the next section. They analyzed data drawn from hogs farms operating in 2004, while we use broiler operations in 2006.

Among hog finishing operations, STA use was closely tied to farm size: about 20 percent of small feeder-to-finish operations provided their animals with growth-promoting STAs in 2004, compared to 60 percent of the largest operations. Farrow-to-finish operations are generally more likely to provide STAs—nearly 40 percent of smaller operations and 75 percent of the largest.[3]

McBride et al. investigated the effects of STA provision on farm level production costs. They recognized that farms were not randomly selected for STA provision, and controlled for the factors that drove selection into STA use in their analysis. Conditional on selection, the provision of STAs seemed to reduce costs at the nursery stage: operations that did not use STAs at the nursery stage had costs that were 30 percent higher than those that did (in a model with controls for the size of the operation, its location, and a variety of production practices). This evidence suggests that STAs reduce mortality and improve feed efficiency among nursery pigs.

In contrast, McBride et al. found little impact of STAs on production costs at the finishing stage (the impact was small and not statistically significant). Any productivity improvement from STAs was not large enough to offset the additional expenses, suggesting the viability of alternative practices or technologies to reduce disease or improve feed efficiency at finishing stages.

Prior literature suggests several tentative findings concerning the economics of STA use in poultry and hog production. STAs appear to reduce feed conversion rates and reduce mortality among poultry and hog operations, but the impacts appear to vary with

[3] Similar patterns hold for STAs provided for disease prevention: the smallest class of producers are less likely to use them than the largest, where 65-75 percent of producers use them.

the type of operation. Moreover, the effect of STAs on production appear to vary with the presence of other practices, and the effects may disappear under some feeding regimens or sanitary protocols.

Survey Data on Broiler Production Operations

Our data are drawn from a large-scale representative survey of broiler producers. That survey forms one version of Phase III of the 2006 Agricultural Resource Management Survey (ARMS), an annual survey of US farms that is the U.S. Department of Agriculture's primary source of information on the financial conditions of farm businesses and farm households, and the production practices of farms. In any given year, several versions of ARMS are distributed; two versions focus on all types of farms, while others focus on producers of specific commodities. A broiler version was included, for the first time, in an ARMS that was conducted early in 2007, with a focus on performance during 2006.[4]

The 2006 broiler version focused on commercial producers of broilers grown for meat--excluding operations who raise broilers for show or for private consumption, as well as egg-laying, hatchery, and broiler breeder operations. For purposes of survey efficiency, standard practice in commodity-specific ARMS versions limits the sample to major production states--in this case, 17 states that accounted for 94 percent of US broiler production in the 2002 Census of Agriculture.[5]

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[4] Further information about ARMS, including downloadable copies of the questionnaires used, can be found at http://www.ers.usda.gov/Briefing/ARMS/.

[5] Specifically, the target population consisted of all operations that produced broilers for meat and that had at least 1,000 broilers on-site at any time during 2006. The states

In order to obtain more reliable production estimates, some types of farms have a higher probability of sample selection. For example, larger operations are more likely to be selected for inclusion than smaller, and selection probabilities also vary across geographic areas. Each sample farm then represents a number of other farms from a similar geographic location and size class. In the broiler version, weights (the number of farms that each sample point represents) range from 3 to 40 operations. When sample observations are weighted to reflect selection probabilities, population estimates for production and other industry characteristics can be generated.

Out of 2,100 operations in the target sample for the broiler version, we received 1,568 useable survey responses from operations that produced broilers for meat during 2006 (a 75 percent response rate). Once the weights are recalibrated for nonresponse, the sample of useable responses represents 17,440 producers with production of 8.44 billion broilers in 2006. Since total nationwide slaughter in 2006 was 8.84 billion broilers, the 17-State sample represents 95 percent of U.S. broiler production.

We focus on 1,546 respondents who reported having a production contract for broilers—the other 22 were independents or processor-owned operations. Farms with production contracts accounted for 98.5 percent of broilers produced in the 17-state sample for 2006 (MacDonald, 2008). Three of those operations had no output in 2006—no broilers were removed during the year—so our initial analyses use the 1,543

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covered by the survey are Alabama, Arkansas, California, Delaware, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia. We focus on commercial growers of broilers raised for meat so as to have a large sample of like operations for analysis.

operations that did have removals. In the later regression analyses of production outcomes, we use a sample of 1,407 operations that reported complete data.

We aim to evaluate the impact of STA use on production outcomes, so we need data on production and on inputs. The survey records the number of broilers removed in each of four different weight classes, and also records the average weight of birds removed in each class. We can then measure the total number of broilers removed as well as total liveweight production. Respondents also report the average mortality rate among chicks placed on the operation in 2006.

The survey provides information on labor, capital, and feed use. For labor, respondents report hours worked on the farm's broiler enterprise by operators and by other unpaid workers, as well as hours worked by hired labor.[6] For capital, respondents report the age, length, and width of every broiler house on the operation, and they also report on house technology--the presence of tunnel ventilation, evaporative cooling, and solid walls.

Broiler producers provide labor and capital to the enterprise, but feed is provided by the integrator. The survey asks respondents for the quantity of feed provided during the year. In many cases, respondents don't know, so item non-response to the feed question is relatively high—only 47 percent of respondents provided feed data, compared to 97 percent for labor and 96 percent for housing capital.[7] In the regression analyses

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[6] The questionnaire asks for average weekly hours worked in each of four quarters, for the operator, for other unpaid labor, for part-time hired labor, and for full-time hired labor. We aggregate those averages across quarters and worker types to estimate annual labor hours.

[7] The feed responses that were provided appear to be of high quality. We estimated feed conversion ratios (FCRs) by dividing total feed provided by liveweight pounds removed.

reported later, we assume that feed is used in fixed proportions to output and omit it from analyses to gain a greater sample size.

We do not have physical measures for other intermediate inputs such as water, electricity and natural gas, and veterinarians services, but respondents did report expenses for those items. We aggregate those into a single measure of intermediate expenses.

The Use of Subtherapeutic Antibiotics in Broiler Production

Our data on STA use is taken from a bank of questions on production practices. Specifically, respondents were asked “Does your contractor...require that your broilers be raised without antibiotics in their feed of water (unless the birds are ill)?”. Respondents could answer “yes”, “no”, or “don’t know”.

“Yes” responses (STAs were prohibited) accounted for 42.4 percent of broiler operations and 44.3 percent of production (table 1). That is, there was little association between the operations size and its use of STAs, in contrast to the hog analysis reported in Key, et al. (2008). Many operators (28.8 percent of farms) reported that they didn’t know, which is not surprising given that STAs may be included as a feed additive, while 27.1 percent reported that STAs were not prohibited.

These data are self-reported and, given the media attention devoted to antibiotic use on livestock and poultry operations, it’s possible that some operators might not want to report about the use of antibiotics. Also, because STAs are often provided by

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The mean FCR was 1.95. The consulting firm Agristats, which collects data from integrators, reports an average FCR of 1.93 for 2008 (conversation with Roselina Angel, University of Maryland poultry nutritionist, March 20, 2009). The American Society of Agricultural and Biological Engineers used an estimate of 1.95 in their 2005 revision of standards for *Manure Production and Characteristics*.

integrators in the feed provided to the operation, many operators may not be sure, even if they report that STAs are or are not used. Thus, there’s good reason to question the quality of the responses received.

One way to check on the quality of responses is to compare them to responses to related questions for consistency. Respondents in the three classes (yes, no, don’t know) differ in their reported use of other production practices as well, and the differences are large and statistically significant. For example, operators who report that STA use is prohibited are considerably more likely to test their flocks and their feed for various pathogens (table 1). They are also much more likely to follow a HACCP (Hazard Analysis and Critical Control Point) Program, to clean their house out after every flock, to follow specified animal welfare requirements, and to use feed that is exclusive from vegetable sources.[8] These practices may all serve as disease prevention substitutes for STAs, and the consistency of responses across practices suggests that the STA response is meaningful.

But we can also perform another consistency check. Seventy-five percent of STA non-users also used a HACCP plan, and there are substantive differences between these operations and others. In table 3, we split STA non-users into those with HACCP plans and those without HACCP plans, and compare them to each other and to operations where STAs are not prohibited. Operations who report that STAs are prohibited, but who do not use a HACCP plan, are about as likely to use the various testing and sanitation procedures as operations who report that STAs are not prohibited.

[8] We use delete-a group jackknife procedures to estimate standard errors for the estimates reported in tables 3 and 4, and test for statistically significant differences in responses across groups.

In contrast, STA nonusers who have a HACCP plan consistently follow testing and animal welfare practices, and are much more likely to report using intensive sanitation practices and feeding from exclusive vegetable sources (table 3). The no-STA/HAACP split appears to identify a set of farms, amounting to just under a third of the sample, who follow a consistent set of practices for animal health management. In the analysis that follows, we define a broad definition of STA prohibition as those respondents who report that STAs are prohibited, and we will define a narrow definition as those who report that they have a HACCP plan and that STAs are prohibited.

STA Prohibition, Technology Use, and Outcomes

In table 3, we compare production technologies and outcomes across four groups: (1) growers who are STA users; (2) growers who don't know if there are STAs in their feed; (3) growers who say they don't use STAs, but who do not have HAACP plans; and (4) growers with HAACP plans who do not use STAs. We compare mean values for housing age, the use of tunnel ventilation, and the use of evaporative cooling. For outcomes measures, we compare mean values for feed conversion rates, mortality rates, and contract fees received per pound of liveweight production. We are particularly interested in comparisons between our two most clearly delineated groups, producers who state that STAs are not prohibited from their operations (column 1), and producers who state that STAs are prohibited and that they use a HACCP plan (column 4).

Non-STA growers have newer houses, on average, than those who use STAs but, while the difference between column 4 and column 1 is statistically significant, it is not really very large—16.6 years versus 18.3 years on average. Growers who use STAs are less likely to have tunnel ventilation in their houses than other growers, and they are also less likely to have evaporative cooling (table 3). Tunnel ventilation and evaporative cooling allow farms to produce more broilers for a given capacity, and hence yield more revenue. Better climate controls may also improve feed efficiency and prevent the spread of disease.

We provide simple comparisons of outcomes in the lower panel of table 3. The mean feed conversion ratio among growers who use STAs is 1.94 pounds of feed per pound of liveweight production, compared to 1.99 among growers in column 4 (HACCP but no STA). This difference, 2.58 percent, is slightly larger than those reported in earlier poultry studies, but it is not statistically significant.[9]

Respondents in column 1 and 4 report identical mean mortality rates of 3.95 percent; interestingly, those who say that they use neither STAs nor a HACCP plan report higher mortality (5.01 percent) and the difference is statistically significant.

Finally, we compare mean contract fees per pounds. Users of STAs are paid 4.89 cents per pound, on average, while those who have a HACCP plan and forego STAs (column 4) receive 5.11 cents per pound, a 4.5 percent difference that is statistically significant. The price difference could reflect other factors, such as the greater average reliance on tunnel ventilation and evaporative cooling among column (4) respondents, but it could also reflect a greater cost associated with the management practices that replace

[9] The survey questions should elicit accurate information for liveweight production, but feed consumption is more problematic. The survey asks for the total amount of feed purchased by the farm, or delivered to the farm, in 2006, but since it does not ask for beginning or end of year stocks of feed, we must assume that delivery matches consumption. This yields some outlier values, and the calculation in table 3 trims the 10 percent of responses that lie below 1.0 or above 3.0.

STAs, costs that growers must be compensated for if they are to be induced to grow broilers without STAs.

A Closer Look at STA Prohibition and Production

Farms that produce broilers without STAs differ from farm that do use them in several ways. On average, they have modest differences in housing characteristics. They may also differ in the types of birds produced, in the location of their farms, and in operator characteristics. We aim to analyze the impacts of STA use on production, while controlling for other factors that may affect production. To do so, we specify a production function for broilers, and we also specify a selection equation to identify the factors associated with non-STA production.

Consider a broiler production function with a simple Cobb-Douglas form:

$$\ln y = \alpha + \sum \beta \ln x_i + \sum \gamma z_j + \eta D + u, \quad (1)$$

where y is the level of output, x_i represents various inputs, and z_j represents features of production technology and operator characteristics that affect production.

Output y is measured by the total liveweight pounds of broilers removed from the farm during 2006. Inputs include labor (L), capital stock (K), and intermediate expenses (E). Labor is total labor hours defined earlier, while capital is total square footage of broiler houses on the operation.[10] We have feed data for less than half of our operations, so we omit it from the analyses reported in this paper.

The z_j include the operator's education, age, and experience in broiler production, and the operation's technological features, product specialization, and geographic location (region). D is a binary variable representing the operator's selection of being a non-STA user.

The non-STA selection is one of the independent variables in equation (1). However, the decision to proceed without STAs may also be endogenous and can be explained by other exogenous factors shown as equation (2).

$$D_i^* = \tau Z_i + u_i; \qquad (2)$$

where **Z**i is a vector of regressors.

Di=1 if Di*>0, 0 otherwise.

If some of the explanatory variables are the same as the variables in production function, the selection problem will arise because

$$E[\delta\varepsilon]\neq 0. \qquad (3)$$

The error terms in equations (1) and (2) can be assumed with a joint normal error distribution to account for the selection bias as follows:

$$\begin{bmatrix}\varepsilon \\ u\end{bmatrix} \text{iid} \sim \text{N}\left(\begin{bmatrix}0 \\ 0\end{bmatrix}, \begin{bmatrix}\sigma^2 & \rho \\ \rho & 1\end{bmatrix}\right) \qquad (4)$$

[10] Some farms may not have operated at full capacity during the year—the farms, or some houses on them, may have shut down or initiated production during the year. We identify such operations by comparing their peak annual inventory with their total removals. In the empirical analyses, those with peak inventory that exceeds one-third of removals are identified as "part year operations" and a dummy variable for them is entered in the model.

The expected production by a non-STA user can be expressed as

$$E[y_i | D_i = 1] = \ln y = \alpha + \sum \beta \ln x_i + \sum \gamma z_j + \eta D + \rho\sigma\lambda i$$

where λi is the inverse Mills ratio. We apply a treatment-effects sample-selection model (Green) to measure the impact of non-STA use on production.

The results of the selection model estimation are reported in table 4, for two different definitions of non-STA use. In column (1), the definition is based only on the response to the STA question; the dependent variable is a dummy that equals 1 for those operations who stated that STA use was prohibited. In column (2), the definition is restricted to those operations who also use a HACCP plan while prohibiting STA use.

Two patterns stand out. First, features of the operation's technology and products matter. Operations producing larger birds are more likely to use STAs (and less likely to ban STA use), compared to operations producing birds that weigh 4.25 pounds or less. Second, management strategies matter, consistent with the patterns reported in tables 2 and 3. Specifically, the coefficients on testing for avian influenza, the use of specified animal welfare rules, strict sanitation procedures, and the use of feed from vegetable sources only are strongly associated with prohibitions on STA use.

We report the results of our estimation of a production function for broilers in table 5. The basic model works well. Increases in housing capacity are associated with increases in production, with an elasticity of 0.88. Given capacity, increases in labor and in intermediate expenses are associated with statistically significant increases in output.

Housing characteristics appear to matter. The coefficients on tunnel ventilation and solid walls, two features of recent housing, are of marginal statistical significance, but they are substantively important. Given housing capacity, tunnel ventilation allows producers to increase annual production by 5.4 percent, while solid walls allows for a production increase of 3.8 percent. Bird type is quite important to production outcomes. Given housing capacity, operations that produce larger birds have substantially higher levels of output for given measures of capital and labor inputs.[11]

The coefficient on STA prohibition is small, and not significantly different from zero. Using the point estimate (-0.0108), operations that do not use STAs realize a 1.08 percent reduction of pounds removed, for given amounts of capital and labor used. That estimate rises to a 1.40 percent reduction when we narrow our definition of an STA prohibition to include only those operations who state that STAs are prohibited and that they use a HACCP plan. Each point estimate is consistent with the findings of Engster at al (2002) and Emborg at al. (2001)—specifically, of small impacts of STA bans on production. However, our estimated standard errors are also quiet substantial.

Discussion and Conclusions

This paper makes two findings that are relevant to research on the use of subtherapeutic antibiotics in broiler production. First, producers who do not use STAs instead substitute a portfolio of other management practices to prevent disease and promote growth. Specifically, non-STA producers are considerably more likely to have a HACCP program and to utilize extensive testing of flocks and feed for pathogens. They are also considerable more likely to clean out and sanitize houses after each flock removal, and to rely exclusively on vegetable feed sources.

[11] All houses with solid walls also have tunnel ventilation, so the two are highly correlated with one another, as well as with another technology, evaporative cooling. Each feature also allows producers to produce larger birds. Collinearity among these features increases their estimated standard errors.

Second, we see no statistically significant impact of an STA prohibition on meat production, in a model that also controls for housing capacity, labor, intermediate expenses, type of bird produced, and housing technology. Our point estimate, of a 1.1-1.4 percent reduction in output, is consistent with the modest effects found in two prior studies, although the 95 percent confidence interval in this analysis easily includes zero.

Even if the production effects were small or zero, that does not imply that alternative approaches are not costlier. Antibiotics are costly, and alternative strategies avoid those costs, but they carry costs of their own, and we have no specific information on the costs associated with the alternative management practices. However, we do find that non-STA producers earn revenues that are about 4 percent greater than producers who use STAs, and this suggest that the costs borne by these producers may be 4 percent greater.

Table 1: STAs and Disease Prevention Strategies on Broiler Operations

Item	*Contractor Prohibits STAs* No	DK/Ref	Yes
	(1)	(2)	(3)
Percent of farms	27.1	30.5	42.4
Percent of production	26.1	29.6	44.3
Production Practices	*Percent of farms following practice*		
(a) Test flocks for avian influenza	52	41	85
(b) Test flocks for salmonella	40	32	75
(c) Test feed for salmonella	34	24	69
(d) Test flocks for other pathogens	38	28	72
(e) Follow a HACCP program	43	36	75
(f) Clean houses after each flock	16	22	47
(g) Follow specific animal welfare rules	34	23	69
(h) Flocks are all-in all-out	86	73	93
(i) Feed from vegetable sources only	6	4	50

Note: The column headed "DK/Ref" refers to those respondents who didn't know whether STAs were prohibited, and those who did not respond to the question. Pair-wise t-tests for differences in proportions indicate that the responses for columns (1) and (2) for practices (c) and (i) are not significantly different from one another. All other pair wise comparisons are statistically significant, at a 90 percent confidence level.

Source: 2006 Agricultural Resource Management Survey, version 4.

Table 2: Combined Disease Prevention Strategies on Broiler Operations

Percent of farms that:	*STAs Used (1)*	*No STAs, No HAACP (2)*	*No STAs, use HAACP (3)*
(a) Test flocks for avian influenza	52	66	92
(b) Test flocks for salmonella	40	48	84
(c) Test feed for salmonella	34	38	79
(d) Test flocks for other pathogens	38	36	84
(e) Clean houses after each flock	16	37	51
(f) Follow specific animal welfare rules	34	38	80
(g) Flocks are all-in all-out	86	87	95
(h) Feed from vegetable sources only	6	26	59

Note: Pair-wise t-tests for differences in proportions indicate that the responses for columns (1) and (2) for practices (a), (e), (f), and (h) are significantly different from one another, while all differences between columns (1) or (2) and column (3) are statistically significant, at a 90 percent confidence level.

Source: 2006 Agricultural Resource Management Survey, version 4.

Table 3: Farm Characteristics and Production Outcomes, by STA Status

	STAs Used (1)	Dk/NR (2)	No STAs, No HACCP (3)	No STAs, HACCP (4)
Housing features				
Average age of houses	18.3^{4}	17.7	16.5	16.6^{1}
% with tunnel ventilation	65.4^{234}	75.0^{1}	76.8^{1}	79.0^{1}
% with evap cooling	66.8^{4}	69.3^{4}	72.6	76.0^{12}
Outcomes				
Mean feed conversion (per lb)	1.94	1.98	2.02	1.99
Mean mortality (%)	4.01^{3}	4.43	5.11	4.07^{3}
Mean fee (cents per pound)	4.89^{4}	4.87^{4}	5.02	5.11^{12}

Note: Superscripts refer to outcomes of tests of significance for differences in means. A column entry is significantly different from entries in columns noted in the superscript at a 90 percent level of confidence.

Source: 2006 Agricultural Resource Management Survey, version 4.

Table 4: Selection Equation—Broiler Operation Without Subtherapeutic Antibiotic Use.

	(1) no sta use		*(2) no sta use, HAACP*	
Variables	coefficient	t-statistic	coefficient	t-statistic
Constant	-1.381	5.38	-2.210	6.27
Operator characteristics:				
Age 64 or over	-0.302	2.79	-0.256	1.77
Education HS grad or less	0.146	1.17	0.087	0.67
Less than 5 years in business	0.377	1.24	0.100	0.23
Operation characteristics:				
Mean housing age	-0.002	0.40	0.0004	0.06
Houses have solid walls	0.188	1.32	-0.009	0.08
Tunnel ventilation	0.196	1.66	0.212	1.33
Birds are 4.26-6.25 pounds	-0.292	2.03	-0.435	2.64
Birds are 6.26-7.75 pounds	-0.327	1.93	-0.455	2.58
Birds are 7.76 pounds or more	-0.208	1.18	-0.361	1.64
Region				
Northeast	-0.624	2.33	-0.617	1.59
Southeast	-0.566	3.10	-0.220	0.89
West	1.159	1.09	-0.971	1.81
South	-0.112	0.67	0.097	0.36
Management practices:				
Test flocks for avian flu	0.711	4.78	0.638	2.52
Test flocks for salmonella	-0.128	0.67	0.144	0.63
Test feed for salmonella	0.110	0.79	0.283	1.85
Specific animal welfare rules	0.452	3.32	0.912	4.82
Flocks are all-in all-out	0.207	1.76	0.086	0.83
HACCP plan followed	0.219	1.86		
Houses cleaned after removal	0.412	3.71	0.379	3.43
Feed vegetable sources only	1.412	13.84	1.257	16.21

Dependent variable in equation (1) is a dummy variable equal to 1 if STAs are prohibited; in equation (2) it is a dummy variable equal to 1 if STAs are prohibited and a HAACP plan is in use.

Table 5: Effect of STA Ban on Production.

	(1) No STA use		*(2) No STA use, HAACP*	
Variables	coefficient	t-statistic	coefficient	t-statistic
Constant	3.349	19.37	3.344	18.82
Inputs (in logs):				
Capital (Housing sq. feet)	0.883	49.10	0.884	48.81
Labor (total annual hours)	0.028	2.14	0.028	2.16
Intermediate expenses ($)	0.117	6.72	0.117	6.70
Operator Characteristics				
Age 64 or older	-0.041	3.21	-0.040	3.15
Education high school or less	-0.014	0.50	-0.014	0.51
Operation characteristics:				
Houses have solid walls	0.037	1.90	0.037	1.88
Tunnel ventilation	0.053	1.70	0.053	1.66
Birds are 4.26-6.25 pounds	0.104	5.80	0.103	5.88
Birds are 6.26-7.75 pounds	0.193	9.64	0.192	9.61
Birds are 7.76 pounds or more	0.259	7.20	0.258	7.26
Part year operation	-0.417	14.72	-0.417	14.63
No STA Use	-0.0108	0.28	-0.0141	0.49
Region				
Northeast	-0.024	0.37	-.0246	0.38
Southeast	-0.072	1.45	-0.071	1.49
West	-0.315	3.60	-0.321	3.35
South	-0.057	1.23	-0.057	1.25
Sigma	-1.463	25.26	-1.462	24.82
Rho	0.057	0.41	0.078	0.69
Sample Size	1407		1407	

Dependent variable: log of total liveweight pounds removed in 2006.

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