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The Economics of Use and Non-Use of Antimicrobial Growth Promoters: The case of Danish Broiler Production

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Abstract

The use of antimicrobial growth promoters was discontinued in the Danish poultry sector in January 1999 on the recommendations of the industry itself and the government. The aim was to ensure consumer food safety. From the economic point of view it was expected that poultry producers would react by restructuring the input set. This paper reports an investigation of the economics of the use and non-use of antimicrobials as growth promoters by tracing the development of broiler output elasticities with respect to inputs and technical change using a production function. We used aggregated panel data from 1994 to 2004 for broiler farms classified as small, medium and large. Our findings suggest that the component of feed in scale elasticities through the period declined, while that of chick stock increased as a result of a decreasing mortality rate and increasing growth rate. The implication is that discontinuing the use of antimicrobial growth promoters has had no effect on broiler production.

Introduction

The ban on using antimicrobial growth promoters in general during the period 1995-2000 in Denmark, and subsequently in the EU as a whole, was primarily motivated by a concern for food safety and human health; i.e. to avoid the potential transfer of unwanted residues and bacterial resistance. This decision, however, has implications for animal health and therefore farm economics in general. Previous studies have shown that the use of antimicrobial growth promoters as a feed additive over time have had some positive animal health effects, such as lowering mortality and morbidity rates that could have resulted from bacterial infections, and an improvement in feed efficiency (WHO, 2002; Wierup, 2001). Improvements in feed efficiency may lower production costs, increase output, and therefore induce lower prices for consumers (Mathews, 2001). The health promoting effects of antimicrobial growth promoters has led some scholars to suggest that in the event of a ban, the therapeutic use of antimicrobials would increase. This would potentially undermine the prevention of possible hazards to human health from zoonosis and from the transfer of bacterial resistance.

There are many arguments for and against the ban. Coffman et al. (1999) provided an extensive account of the use of drugs with special reference to antimicrobials in livestock production. Their study suggested that although resistance was low, there is a link between the use of antimicrobials in livestock and the incidence of bacterial resistance; i.e. when drugs are used to treat human diseases.

Referring to the work of others, Coffman et al. (1999) reported that antimicrobial growth promoters are most effective in animals under stress, as result of both poor nutrition and sanitation. Hayes, Jensen and Fabiosa (2002) later reported the same view. Coffman el al. (1999) suggested that some livestock producers (e.g. antimicrobial growth promoter free producers) might actually benefit from a ban. This would be the case if the cost of production without antimicrobial growth promoters was passed on to consumers in the form of higher prices. Consumers would thereby bear the cost of a ban (Hayes et al., 2001 and Mathews 2001).

Previous studies of the effect of a ban on antimicrobial growth promoters have focused on consumer and producer gains (Hayes et al., 2001 and Mathews, 2001). These studies have suggested that consumers suffered losses as a result of anticipated high prices while the impact on producers has been mixed. Wade and Barkley’s (1992) study of the pig sector also indicated that producers would gain from higher consumer prices. On the other hand Hayes et al. (2001) and Mathews (2001) considered that producers would experience losses due to their costs being higher than the eventual consumer price increases. The studies have, however exhibited distinct unawareness of the eventual change in producer behaviour or of the producer decision-making process in response to a ban on antimicrobial growth promoters.

The aim of this study is to identify the change in producer behaviour or in the producer decision-making process and evaluate the impact of the ban on the use of antimicrobial growth promoters on economic efficiency of broiler production. Specifically, we estimate the output elasticities with respect to variable inputs over time and assess whether the ban has altered the productivity parameters for broiler producers. Using long period data, we are able to evaluate economic efficiency and substitutability of inputs and the impact of technical change through the pre-post period of the ban. Thus, in essence we evaluate how groups of broiler producers adjust their inputs to accommodate the anticipated cost increases from not using the antimicrobial growth promoter technology.

The rest of the paper develops as follows: The next section provides information on the issue of resistance and the use of antimicrobials in poultry and broiler production in Denmark. The sections on the analytical methodology and data, results, discussion, and concluding remarks follow in that order.

Resistance and the use of antimicrobial in the Danish poultry sector

Antimicrobials in the poultry sector have three uses: (1) therapeutically for treatment against bacterial infection, (2) preventively as a measure against a parasitic infection, coccidiosis, and (3) as growth promoters to increase feed efficiency, by preventing bacterial infections.

Prior to the year 1999, when the use of antimicrobial growth promoters was discontinued in the poultry sector, antimicrobial resistance in broilers and broiler meat was high for some antimicrobials and bacteria. For example resistance by *Enterococcus faecium* to the antimicrobials tetracycline and erythromycin were 20% and 76% respectively and the resistance to growth promoters was 80-100%, decreasing subsequent to the ban (DANMAP 1997, DANMAP 2005).

An estimated five metric tons of antimicrobial growth promoter was used in Danish poultry in 1998, i.e. 26mg/kg poultry meat before the ban. Prior to the year 2000, the amount of antimicrobial utilised for therapy was unknown. However, during 2001-2005, the annual usage of therapeutic antimicrobials for poultry in Denmark varied between

0.4 and 0.6 metric tons. The consumption for broilers in 2005 was 138 kg, corresponding to 0.77 mg/kg broiler meat. The use of coccidiostats, which include ionophores that have an antibacterial effect against the volatile coccidial infection in poultry was, in 1990, 117 mg/kg broiler meat reaching a peak of 142 mg/kg broiler meat in 1999. Since then its use in broiler production has on average decreased by 45 % during the period 2000 to 2004 and more specifically fell by 49% in 2004. Thus, therapeutic antimicrobial usage has remained at a very low level and the use of coccidiostats has decreased relative to the level in 1990 after the ban on antimicrobial growth promoters in Denmark.

Leaders in the broiler-production industry have argued against the ban on the grounds of higher mortality and morbidity caused by necrotic enteritis (a poultry disease). It was anticipated that necrotic enteritis would ensue from discontinuing antimicrobial growth promoters. In Sweden, outbreaks were prevented by the continuous use of prescription in-feed antimicrobials in the first two years of the ban. Thereafter, necrotic enteritis was prevented by various management procedures with treatment only in the case of outbreaks (Wierup, 2001). In Denmark, the reported flock incidence of necrotic enteritis increased (from one-two yearly outbreaks to 25 cases in a population of >1700 flocks) the year after the ban on antimicrobial growth promoters in 1999. Some scholars have however argued that the increase might have arisen from an increased willingness to report, due to the establishment of an industry fund to compensate producers for losses associated with necrotic enteritis following the discontinuation (Tornøe, 2002). With these caveats in mind, it is relevant to evaluate how broiler producers have reacted to the ending of the use of antimicrobial growth promoter technology.

Analytical methods and data:

Analytical methods

We formulated and estimated a parametric production function model to evaluate the production structure, using a data set spanning the years 1994 to 2004. The analysed production function is a Cobb-Douglas one, where input elasticities are linear functions of time. The model specification and estimation follows that of Heshmati, Kumbhakar and Hjalmarsson (1995). It differs from their model by not including fixed capital inputs because of the lack of information. The choice of the functional form specification is due to the limited number of observations ($n*t = 33$). The model specification is as follows:

$$
\begin{aligned}
\ln Y_{it} &= \mu_0 + \sum_{j=1} \beta_j \ln X_{jit} + \beta_t t_i \\
&\quad + \sum_{j=1} \beta_{tj} t_i \ln X_{jit} + \frac{1}{2}\beta_{tt} t^2 + \mu_i + e_{it} \\
&\quad (i = \text{small, medium and large farm groups}) \\
&\quad (t = 1994, \cdots, 2004) \\
&\quad (j = \text{chick, feed and sundry inputs}) \qquad [1]
\end{aligned}
$$

where Y_{it} is broiler output per production unit group i, in time t,; X_j are inputs; the time trend, t, and its quadratic term represents the technical change; μ_i is the group specific fixed effects of the three production unit groups and μ_0 is the intercept. The small production unit represents farms with a broiler capacity of less than 25 000 birds per rotation, that for the medium farm group is 25 000 to 100 000 birds, while the large farm group is for those with 100 000 birds per rotation (see for example DPC, 2004, p. 74); e_{it} is the error term, and is $N(0,\sigma^2)$.

In equation [1], the output elasticities vary over time and reflect changes in the production structure. The output elasticities are also the share of input costs relative to total revenue under competitive market conditions. In addition, farm effects are directly extracted from eventual inefficiency in the production system. The technical change represented by time can be decomposed into a pure time effect and a biased part associated with the inputs. The model shows the trend in output productivities with respect to inputs, elasticities and technical change over time, to identify any substitution during the post ban period. From the production function in equation [1] the output elasticities, ε, with respect to inputs is given by:

$$\varepsilon_j = \frac{\partial \ln Y}{\partial \ln X_j} = \beta_j + \beta_{tj} t \qquad [2]$$

The scale of size (S) is given by;

$$S_{\varepsilon_j} = \sum \varepsilon_j = \sum \frac{\partial \ln Y}{\partial \ln X_j} = \sum \beta_j + \beta_{tj} t \qquad [3]$$

The rate of technical change (TC) is given by:

$$\varepsilon_{TC} = \frac{\partial \ln Y}{\partial t} = \beta_t + \beta_{tt} t + \sum_j \beta_{tj} \ln \mathrm{X}_{\mathrm{jit}} \qquad [4]$$

If the technical change is not neutral (i.e. $\beta_{tj} \neq 0$), then the bias for technical change is:

$$B_{jt} = \frac{\partial \ln X_j}{\partial t} = \frac{\beta_{tj}}{\varepsilon_{j_t}} + \varepsilon_{TC} \qquad [5]$$

Hence technical change bias is input *j* using if $B_{jt} > 0$ and input *j* saving if $B_{jt} < 0$.

Data

The data for the analysis comes from the annual reports of the Danish Poultry Council (DPC), covering the years 1994-2004. The data represents nearly all Danish broiler producers (between 333 and 277 for 1994 and 2004). The data for the analysis is from aggregates of small, medium and large farms, based on the size of broiler production per rotation. The number of farms in each group through the period is on average 46, 202 and 57 for small, medium and large farms respectively. Average for outputs and inputs are plotted for the period 1994 through 2004 (Figure 1).

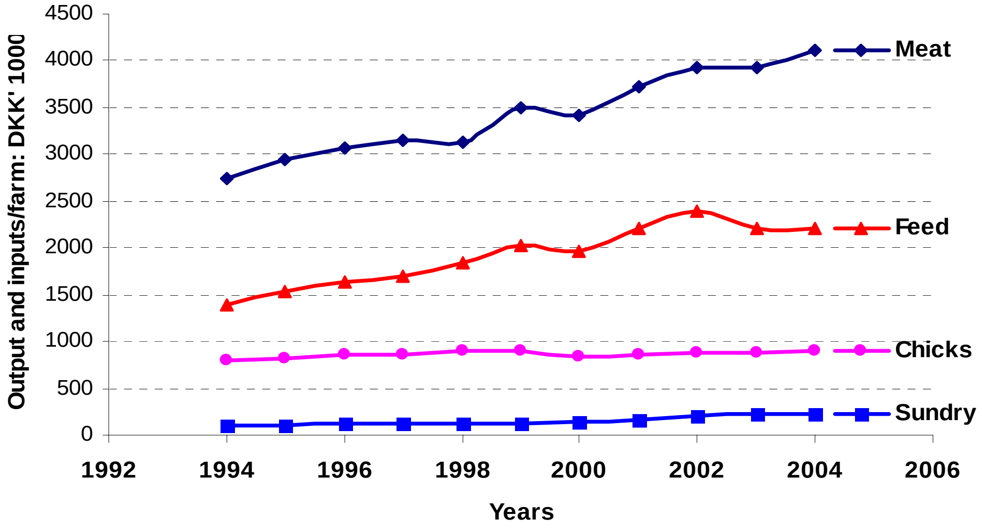

Figure 1: Averages of meat output, chick stock, feed and sundry inputs, 1994-2004

The output, Y, is the total broiler income in Danish Krone, DKK, converted to the year 2000 prices using the producer price index for poultry. The input variables, X_j, for chicks, feed and sundries are total expenditures also in Krone and converted into the year 2000 prices using a livestock feed cost price index for feed, and a livestock and requisites cost price index for chicks and sundries. The time variable t, is coded 0, 1, 2, 3, …, 10 for 1994 through 2004. The chosen parameterisation of time enables estimating elasticities at a base point in 1994. This implies that output elasticities with respect to inputs for subsequent years can be compared to the 1994 estimates, the year prior to the first ban on antimicrobial growth promoters. The total expenditure for sundries includes among other items those for veterinary services, medications, cleaning, water, energy and solutions for disinfecting broiler houses.

Results

The test that the estimated model error-term, e_{it}, in equation [1], is $N(0,\sigma^2)$ was not rejected. The parameter estimates for the production function analysis are presented in Table 1.

Table 1. Production function: least square parameter estimates

Variables	Symbol	Parameter Estimates	Standard error	t_value	Significance Level
Constant #	μ_0	2.009	1.001	2.01	0.057
Chick stock	β_1	-0.504	0.376	-1.34	0.194
Feed	β_2	1.363	0.387	3.52	0.002
Sundry	β_3	0.066	0.117	0.57	0.576
Time	β_t	-0.020	0.046	-0.44	0.662
Time^2	β_{tt}	0.006	0.002	3.00	0.005
Time x chick stock	β_{t1}	0.101	0.047	2.15	0.043
Time x feed	β_{t2}	-0.102	0.049	-2.10	0.048
Time x sundry	β_{t3}	0.002	0.019	0.13	0.901
Small_farms	μ_1	-0.236	0.126	-1.87	0.075
Large_farms	μ_3	-0.024	0.019	-1.25	0.226
Number of observations	33				

represents medium size farms

Except for sundry inputs all the parameter estimates are significant. The fixed effect of the group of large farms is on average not significantly different from that for medium sized farms, which is captured by the intercept. The estimated value of -0.024 for large farms suggests that this group produces on average 98% ($e^{-0.024}$) of a unit change for each unit change in the production of medium sized farms. This is despite the fact that the large producing group accounts for about 19% of producers. The group of small farms with 15% of producers and fewer than 25 000 birds per rotation, on average differs moderately from the medium and the large farm groups. The estimate of -0.236 suggests they produce 79% of every unit change of that of the production of the medium sized farms. The coefficients β_1, β_2 and β_3 are output elasticities with respect to the inputs chick stock, feed and sundries in 1994. As shown, it is mainly the feed input that determined the output productivity in 1994. The estimated yearly output elasticities, with respect to inputs, technical change and their biases are provided in Tables 2 and 3.

Table 2. Output elasticities with respect to inputs, scale, technical change (TC) and input biases by year

Year	Chick		Feed		Sundry		Scale	TC		Pure TC
	Estimate	SE[#]	Estimate	SE	Estimate	SE	Estimate	Estimate	SE	Estimate
1994	-0.504	0.376	1.363	0.387	0.066	0.117	0.926	-0.0519	0.0028	-0.0204
1995	-0.403	0.332	1.261	0.340	0.069	0.101	0.928	-0.0464	0.0030	-0.0087
1996	-0.301	0.288	1.160	0.294	0.071	0.086	0.929	-0.0366	0.0027	0.0030
1997	-0.200	0.246	1.058	0.249	0.074	0.074	0.931	-0.0276	0.0028	0.0147
1998	-0.099	0.206	0.956	0.206	0.076	0.064	0.933	-0.0200	0.0028	0.0264
1999	0.002	0.170	0.854	0.166	0.078	0.059	0.935	-0.0170	0.0023	0.0382
2000	0.103	0.140	0.752	0.131	0.081	0.061	0.937	-0.0107	0.0020	0.0499
2001	0.205	0.121	0.650	0.108	0.083	0.068	0.938	-0.0070	0.0014	0.0616
2002	0.306	0.119	0.549	0.104	0.086	0.079	0.940	0.0002	0.0012	0.0733
2003	0.407	0.135	0.447	0.122	0.088	0.093	0.942	0.0226	0.0006	0.0850
2004	0.508	0.163	0.345	0.153	0.091	0.108	0.944	0.0347	0.0021	0.0968

[#] SE is standard error

In Table 2, it can be seen that output elasticity with respect to feed input decreases from 1.36 in 1994 to 0.34 in 2004 (Table 2, column 4) and is significantly above zero through the period. The output elasticity with respect to sundry inputs (column 6) has increased but is not significantly different from zero. The output elasticity with respect to chick stock (column 2) is negative for the first 5 years, and not significantly different from zero for 1994 through 2001. However, from 2002 through 2004 the estimate was significantly different from zero. Hence 3 years after discontinuing the use of antimicrobial growth promoters the opposite direction in the elasticity estimates suggest that input substitution seems to exist between feed and chick stock inputs and continues to 2004. This was not explicit in the estimated model. The pure-technical change rose from negative 2% in 1994 to 9.7% in 2004 (Table 2, last column), which suggests that since 1994, pure-technical change seems to capture the positive effects of other factors (e.g. the breed of chick stock) not included in the model. In interpreting the output elasticities as cost shares, the results in Table 2 indicates that farmers are paying high prices for improved breeding stock and increasing their expenditure on sundry inputs. As later shown in Figure 2, the resulting increase in the growth rate of birds, reduced the cost to feed ratio (i.e. decreasing cost share).

Table 3. Estimates for Non-pure technical change and input biases by year

	Non-Pure-TC		Chick Biases##		Feed Biases		Sundry Biases	
YEAR	Estimate	SE#	Estimate	SE	Estimate	SE	Estimate	SE
1994	-0.0314	0.0028	-	-	-0.1266	0.0028	-0.0156	0.0028
1995	-0.0377	0.0030	-	-	-0.1272	0.0030	-0.0114	0.0030
1996	-0.0396	0.0027	-	-	-0.1244	0.0027	-0.0027	0.0027
1997	-0.0423	0.0028	-	-	-0.1239	0.0028	0.0051	0.0028
1998	-0.0464	0.0028	-	-	-0.1265	0.0028	0.0117	0.0028
1999	-0.0551	0.0023	-	-	-0.1362	0.0023	0.0137	0.0023
2000	-0.0606	0.0020	0.9681	0.0020	-0.1460	0.0020	0.0191	0.0020
2001	-0.0686	0.0014	0.4876	0.0014	-0.1636	0.0014	0.0219	0.0014
2002	-0.0731	0.0012	0.3312	0.0012	-0.1854	0.0012	0.0283	0.0012
2003	-0.0625	0.0006	0.2712	0.0006	-0.2053	0.0006	0.0499	0.0006
2004	-0.0621	0.0021	0.2338	0.0021	-0.2605	0.0021	0.0613	0.0021

SE is standard error ; ## Non applicable values due to corresponding negative or close to zero estimates for the elasticities

From Table 3, the substitution effect between feed and chick input is also reflected by the technical change biases for the input variables from the year 2000 (columns 4, 6 and 8). While the technical change bias for feed is input saving, that for chick stock is input using. The technical change bias for sundry inputs has been input saving for 1994 through 1996 and since then input using, reflecting the emphasis on sanitation after the onset of the first ban in 1995.

Discussion and concluding remarks

We have investigated the impact of ending of the use of antimicrobial growth promoters by estimating a Cobb-Douglas production function with input coefficients being a function of time using aggregated data. In our model formulation we assumed that farms in each group are homogenous, which may be a limitation. The number of data observations did not allow us to formulate and estimate a translog function hence limiting our explicit evaluation of the substitution between inputs. However, by including group dummies we capture the heterogeneity between groups. In addition, the impact of time on input estimates allows us to trace the use of specific inputs over time. Therefore our evaluations are across individual farm units and are generally based on the reactions of farmers aggregated in groups by size of production.

With the above caveats in mind, we found that the use of feed decreased at a constant rate of 0.10 percent points through the given time period. The decrease turns out to be mainly substituted for by an increase in chick stock with a minor contribution from sundry inputs. These observations are represented by the output elasticities with respect to the inputs.

Questions can be raised as to whether the development of the output elasticities with respect to feed and chick stock inputs has been due to not using of the antimicrobial growth promoter technology. From Figure 2, we see that the efficiency of production evaluated by mortality and growth rates of chick stock, suggests that farms can maintain their production without antimicrobial growth promoters but by increasing sundry inputs and using improved breeds of chick stock. Higher sundry inputs, can lead to improved hygiene and sanitation management. Since the late 1990's there has been an increased focus on hygiene, sanitation and preventing bacterial infection in broiler production, mainly to counteract the high incidence of salmonella infection and hence lower the mortality rate.

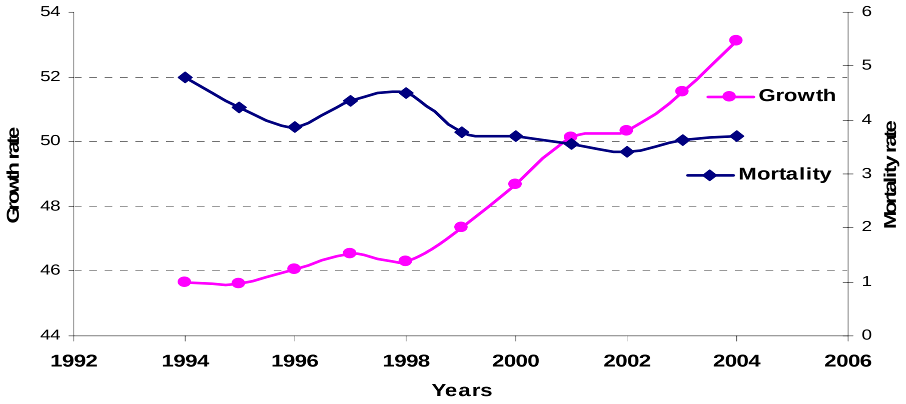

Figure 2: Yearly average growth and mortality rates of broiler birds: 1994-2004

Furthermore, growth rates of chick stock increased due to the use of improved breeding stock, which raised the feed conversion ratio i.e. improved feed utilisation. The choice and the distribution of breeding stock changed during the period 1999 through 2001. The use of a dominant breed dwindled superseded by a specific breed. This specific breed eventually replaced the dominant breed during 1994 through 2002 due to its higher growth rate (DPC, 2004). The improvement in breeding stock is captured by the pure technical change (Table2).

The scale elasticity of size measure averaged about 0.94, suggesting that the poultry sector is on average generating decreasing returns to scale. However, it should be noted that this could be due to our model specification, which did not include fixed capital inputs. However, we still believe that the model reflected the impact of use and non-use of antimicrobial growth promoters. This is because antimicrobial growth promoters are directly related to the feeding regime.

A previous Danish study, (Emborg *et al*., 2001), using data from the early post-discontinuation period, investigated the effects on broiler production of discontinuing the use of antimicrobial growth promoters. The results of their statistical analysis suggested that this had a negligible reduction in the feed conversion ratio with no change in mortality rate and kilograms of broiler produced per square meter. We found the role of feed input in scale elasticity is decreasing and that of the purchased chick stock input is increasing. Thus, given our findings, the decrease in mortality rate and the increased growth rate after the ban, indirectly suggests that the feed conversion ratio (feed efficiency) is improving without the use of antimicrobial growth promoters. The results indicate that for the poultry industry, the pre-ban harboured fear about an increase in mortality and a reduction in output, was not realised.

Other researchers, Hayes et al. (2001), Mathews (2001) and Hayes, Jensen and Fabiosa (2002) in investigating the impact of banning the use of antimicrobial growth promoters, emphasised the cost to producers and consumers. The information provided by their work is relevant for monetary quantification of the impact of an eventual ban for producers and society. Our study is not comparable to theirs because our focus has been on the behaviour or decision-making of groups of producers, which is expressed by the econometric elasticity parameters. We believe these elasticities expressed producers' adjustment to not using antimicrobial growth promoters.

Our findings therefore complement the previous studies by evaluating and providing specific knowledge about the production technology for a longer period before and after the complete discontinuation of the use of antimicrobial growth promoters. For the producers in countries where the decision as to whether or not to ban is still under debate, the results provide useful information on the response of Danish producers as reflected in the estimated model. In this case producers increased the productivity of chick inputs through decreasing mortality by improving hygiene and sanitation management. This provided the basis for efficient transformation of feed intake with subsequent higher growth rates. The sum effect is the avoidance of input costs attributed to the use of antimicrobial growth promoters.

In conclusion, this study demonstrates that it is possible to avoid the use of antimicrobial growth promoters in broiler production without experiencing the anticipated negative impacts.

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