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An econometric approach to prediction of optimal broiler production cycle using the coefficient of economic efficiency

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ABSTRACT

The present paper uses mathematical methods and presently available statistical techniques to economically characterize broiler meat production under the economic conditions of Turkey. State-of-the-art econometric modelling and classic methods used currently for regulatory decision-making in the world are described. Based on this evaluation, needs for future research are defined. It is concluded from our work that mathematical modelling of the economically optimal production time using the coefficient of economic efficiency would improve economic profitability. The classical method of economic optimization in animal production is not suitable for all kinds of economic assessments. A range of different approaches is necessary so that the method used is the most appropriate for the data available and for the economic risk characterization issue. In the present study, the basic data used for evaluation were: total marginal income, total marginal food *plus* cumulative chicken cost, total marginal net income, marginal food conversion ratio cost *plus* marginal chicken cost, and the coefficient of economic efficiency. After the mathematical function between production period and coefficient of economic efficiency was calculated, the optimum production period was predicted. Then, the total coefficient of economic efficiency was estimated by integration of the calculated mathematical function.

KEY WORDS: mathematical model, broiler production

INTRODUCTION

The broiler sector of Turkey is one of the fastest growing sectors in the country. Broiler farms are considered one of the highest priority areas that have gained major support and incentives in government policy. Broiler farms in Central Turkey require substantial investment costs and competent management. Some of the farms have experienced a wide range of technical and economic problems. Measurement of the economic efficiency of broiler production is an important issue in developing countries such as Turkey. A measure of producer performance is often useful for policy purposes, and the concept of economic efficiency provides a theoretical basis for such a measure. Efficiency in production can be defined in terms of the production function that relates the level of various inputs (Banker et al., 1984). Economic efficiency is a measure of a farm's success in producing maximum output from a given set of input; in other words, economic efficiency refers to the physical relationship between inputs used in the production process. Economic efficiency measures output relative to that of the efficient isoquant. Efficient farms produce on the production frontier or, alternatively stated, on the efficient isoquant. The concept of economic efficiency relates to the question of where a firm or farm uses the best available technology in its production processes (Chavas and Aliber, 1999).

In general, the aim of measuring farm level efficiency is to estimate the frontier that envelopes all the input/output data with the observations lying on the frontier described as economically efficient. Observations lying below this frontier are considered to be economically inefficient (Fraser and Cordina, 1999). In animal production farms, estimation of optimum production cycles is very important in respect to economic production (Scott et al., 1982). A classic calculation method would not be more suitable for either economic optimization assessment or for all databases. The classical method only takes into consideration marginal net income *minus* marginal cost without making any analysis of the mathematical function between total marginal net income and marginal costs. Mathematical modelling of the production time-net income relationship would improve the economic assessment process (Parlat et al., 1999). The optimal production period depends on the realization of maximal income from a unit production factor (Doll et al., 1984). It could be calculated realistically by a mathematical function between dependent and independent variables (Debertin, 1986). Therefore, determination of the optimum production period for maximization of total net income has major importance. Also, functional analysis of production gives information about maximization of net income (Connor, 1973). Groen (1989) indicated that optimal production time influences relative contributions of improvements of animal traits to economic efficiency of production. Uncertainty over future production time is an important factor and must be considered when deriving economic values. Hirooka and Sasaki (1998) found that, for some animal products, there are significant time-to-time variations in economic values. In addition, optimal production time and prices of animal products are seldom known for certain at the time that a producer must make decisions about when and how much animal products to produce. Increasingly, animal producers are exposed to unpredictable competitive markets for inputs and output, so that economic production time risk is often significant and may increase over time (Hardaker et al., 1997). To estimate the optimal economic production time, animal producers have used various mathematical models. Profit econometric models assume perfect knowledge of all relevant parameters. Ideally, animal producers should use economic models that take into account the fact that knowledge is imperfect and economic circumstances are dynamic in time. The aim of the present study was to consider the optimal production time for broiler producers by using an econometric model. Optimum production time for an animal production system can be estimated by the mathematical relationship between production period and coefficient of economic efficiency.

This function makes it possible to estimate optimum production time, namely, time of minimum movement variation for the coefficient of economic efficiency. According to Gossen's law of diminishing returns, the optimum economic production level could be reached when marginal cost is equal to marginal income (Heady, 1968).

This article was prepared given the need for a new approach to calculating optimum broiler production time with regard to compensation of various deficiencies.

MATERIAL AND METHODS

Theory

The most basic assumption of a production function is that a mathematical relationship exists between production time and coefficient of economic efficiency:

$$\boldsymbol{y} = f\{\boldsymbol{x_1}, \boldsymbol{x_2}\}$$

where $\boldsymbol{y}$ is the coefficient of economic efficiency and $\boldsymbol{x_1}$, $\boldsymbol{x_2}$ are vectors of production time. At the same time vectors $\boldsymbol{x_1}$ and $\boldsymbol{x_2}$ represent total marginal net income and marginal cost, respectively. Farms produce $\boldsymbol{y}$ output by using two inputs ($\boldsymbol{x_1}, \boldsymbol{x_2}$). A constant returns to scale production function is assumed. In general, for econometric models, the optimal value of $\boldsymbol{y}$ depends on prices and costs of animal products. The coefficient of economic efficiency and time equation give the profit or risk-rated profit function. This function reflects the solution to the firm's optimization problems.

Production data of a commercial broiler producer farm having a total of 10,000-broiler chicken capacity was used for this study. The broiler chicken cost (BCC) was \$0.40/chicken, total BCC was \$4,000. Also, the food price was \$0.25/kg and broiler meat price, \$1.75/kg. In the present study, the main expenses were BCC and food cost, as these expenses accounted for at least 90% of total expenses. Therefore, other expenses (about 10%) could be excluded from the calculations. The specification of the equation in our example reflects the fact that data available the production of many heads of livestock is best suited to determine the coefficient of economic efficiency and production time.

First, marginal food intake (MFI), marginal weight gain (MWG), cumulative weight gain (CWG), marginal food conversion ratio (MFCR), total marginal food cost (TMFC), marginal food conversion ratio cost (MFCRC), marginal chicken cost (MCC) and cumulative chicken cost (CCC) *per* chicken for each period (7 weeks) were calculated. Then, total marginal income (TMI), total marginal food *plus* cumulative chicken costs (TMC), total marginal net income (TMNI), marginal food conversion ratio cost *plus* marginal chicken cost (MC) and coefficient of economic efficiency (CEE) *per* chicken for each period were calculated. The coefficient of economic efficiency (CEE) is calculated as follows:

CEE = Total marginal net income / Marginal costs (Heady, 1968).

After this step, the mathematical function between production period and (x) and CEE (y) is calculated. Finally, the optimum production cycle was estimated *via* a derivative function of the calculated mathematical model. In this model, production period (x) and CEE (y) were used as independent and dependent variables, respectively. Then, the derivatized function was equalized to zero and the economical optimum production cycle was estimated.

That is: $f'(x)=dy/dx=0$

The calculated x value *via* the derivative function is mathematically the optimum production time (Abromowitz and Stegun, 1972). By using the calculated x value for $f(x)$ the marginal CEE value for optimum production time could be estimated. Also, total CEE values could be calculated by integration of $f(x)$ from beginning to optimum production time.

The data were subjected to analysis of regression (Steel and Torrie, 1980) by using SPSS (1988) and MINITAB (1995) software.

Numerical example and practical implication

Marginal food intake (MFI), marginal weight gain (MWG), cumulative weight gain (CWG), marginal food conversion ratio (MFCR), total marginal food cost (TMFC), marginal food conversion ratio cost (MFCRC), marginal Chicken Cost and Cumulative Chicken Cost *per* chicken for each period are shown in Table 1. CCC *per* chicken for each period was calculated as follows:

TABLE 1

Marginal food intake, marginal weight gain, cumulative weight gain, marginal food conversion ratio, total marginal food cost, marginal food conversion ratio cost, marginal chicken cost and cumulative chicken cost *per* chicken for each period

Period week	Marginal food intake kg/ period	Marginal weight gain kg/ period	Cumulative weight gain kg/period	Marginal food conversion ratio (FCR) kg/kg/period	Total marginal food cost $/period	Marginal FCR cost $/period	Marginal chicken cost $/period	Cumulative chicken cost $/period
1	0.131	0.114	0.114	1.149	0.03275	0.28725	3.508	0.40
2	0.297	0.234	0.348	1.269	0.07425	0.31725	1.150	0.27
3	0.428	0.304	0.652	1.408	0.10700	0.35200	0.610	0.19
4	0.643	0.384	1.036	1.675	0.16075	0.41875	0.390	0.15
5	0.871	0.449	1.485	1.940	0.21775	0.48500	0.270	0.12
6	1.055	0.472	1.957	2.235	0.26375	0.55875	0.200	0.09
7	1.230	0.472	2.429	2.606	0.30750	0.65150	0.160	0.08

TABLE 2

Total marginal income, total marginal food *plus* cumulative chicken costs, total marginal net income, marginal food conversion ratio *plus* marginal chicken costs and coefficient of economic efficiency *per* chicken for each period

Period week	Total marginal income $/period	Total marginal food *plus* cumulative chicken costs $/period	Total marginal net income $/period	Marginal FCR *plus* marginal chicken costs $/period	Coefficient of economic efficiency
1	0.1995	0.43275	-0.23325	3.79525	-0.0610
2	0.4095	0.34335	0.06615	1.46725	0.0451
3	0.5320	0.29244	0.23976	0.96200	0.2492
4	0.6720	0.31051	0.36149	0.80875	0.4469
5	0.7858	0.33898	0.44682	0.75500	0.5918
6	0.8260	0.35815	0.46785	0.75875	0.6166
7	0.8260	0.38302	0.44298	0.81150	0.5458

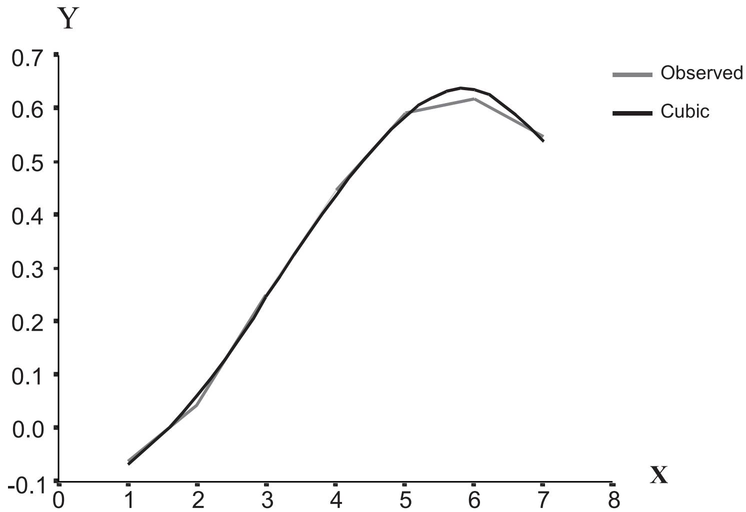

Figure 1. Graph of relationship between production period (X) and coefficient of economic efficiency (Y)

CCC of 1st period (CCC_1) = (Chicken cost / MWG)*CWG of 1st period(MWG_1).

Marginal income (MI), marginal FC *plus* chicken cost (MFCC) and marginal net income (MNI) *per* chicken for each period were shown in Table 2.

MNI *per* chicken for each period were calculated with the figures from Table 1 and Table 2. MNI *per* chicken for each period was calculated as:

MNI *per* chicken of 1st period (MNI_1) = MI *per* chicken of 1st period (I_1) - MFCC *per* chicken of 1st period ($MFCC_1$)

The mathematical function was calculated to determine the relationship between *x* and *y*. The relationship between *x* and *y* was shown in Figure 1. The estimated regression equation, coefficient of determination and variance analysis of the relationship between *x* and *y* are shown in Table 3. The mathematical function between *x* and *y* is as follows:

$$y=f(x)= -0{,}086781-0.052186x+0{,}079966x^2-0.008536x^3$$

where:

y is CEE (dependent variable)
x is the production period (independent variable).

TABLE 3

Estimated regression equation, coefficient of determination and variance analysis of relationship between production period and coefficient of economic efficiency

Source	SS	df	MS	F	P
Regression	0.44847312	3	0.14949104	541.70669	0.0001
Residuals	0.00082789	3	0.00027596		

Estimated regression equation[a] : $\hat{Y} = -0.086781 - 0.052186x + 0.079966x^2 - 0.008536x^3$
Determination of coefficient : $R^2 = 0.99631 \pm 0.01661$

[a] production period (x)
coefficient of economic efficiency (y)

In this equation, if the function is derived and then equalized to zero, the optimum production period can be calculated. That is:

$$y' = f'(x) = dy/dx = -0{,}025608x^2 + 0.159932x - 0.052186 = 0$$

When this function is solved, *x* is calculated as 5.92 weeks. That is, the optimal production period is 41.44 days (5.92*7) for the present study. By using the calculated x_{value} in the *f(x)* function, the maximum CEE value during the production period was obtained as:

$$f(5.92) = 0.63579 \text{ (maximum CEE value).}$$

As seen from Table 2, CEE for 6 weeks was maximum. Also, total CEE *per* chicken could be calculated by integration of *f(x)* from the beginning to the 5.92[nd] week. That is;

$$\int_0^{5.92} f(x) = \int_0^{5.92} -0.524474 + 0.340693x - 0.029073x^2 = 1.48198.$$

RESULTS AND DISCUSSION

The estimated coefficients are highly significant (Table 3). These results reveal substantial inefficiencies in broiler production in the central region of Turkey. By this measure, this farm could reduce its costs without reducing its output when CEE is considered for economic optimization. The economic efficiency for a sample of a broiler farmer was determined by the econometric approach including the estimation of an input-oriented mathematical model. Greater differences in economic values were observed when economic values were compared based on the econometric optimization model. Generally, the difference in optimal values of the management variable depends on market, economic and environmental conditions in specific commercial broiler operations. The example is very simplified, with only one output and one input variable, but does illustrate that econometric models can have a large impact on economic profitability. There are great differences between traditional calculations and econometric functions. From the economic point of view, production functions represent a better model of the real economic situation and producer's choices. Marginal economic production of any factor could be realized when the factor cost is equal to product price. The results of this study are in agreement with other explanations of functional analysis of production (Doll et al., 1968; Heady, 1968; Cramer et al., 1979). This also means that a significant proportion of broiler production is lost due to economic inefficiency.

The profitability defined in this study consisted of a quadratic function. A number of different approaches have been developed to elicit the required information from decision makers to be able to encode their preferences into a suitable utility function (Hardaker et al., 1997). Estimating the variance of economic profitability is a complex issue because it depends on production functions and economic parameters. Some of these calculation methods and parameters needed concerning variations in economic values are often made implicitly.

Also the results suggest that there is an opportunity to improve the economic efficiency of broiler production in the region. It may be appropriate to implement training programs for the producers of broiler farms with a goal of improving economic efficiency. Additional research will be necessary to determine the comprehensive consequences of the methods of efficient broiler production.

The purpose of this study was to contribute to the evaluation of the performance of economic broiler production under the economic conditions of Turkey. This study generated estimates of an econometric production function for a broiler farm in the central region of Turkey. A classic calculation method would not be suitable for economic optimization assessment, or for all databases. Mathematical modelling of the production time-net income relationship would improve the economic assessment process. Future refinements to the production time-net income characterization should incorporate more clearly the extent of uncertainty and variability in the resulting output.

CONCLUSIONS

It is apparent that the optimum production period for this study is 5.86 weeks. The method economically makes it possible to calculate the optimum production period in broiler farms. This model should be evaluated as a universal calculation method, whereas the optimum production period may change according to the economic conditions of a given country. It is important that there is a way to calculate the optimum production period. The superiority of this model will appear when it is used more frequently in experimental studies and the results applied in practice.

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STRESZCZENIE

Ekonometryczny sposób szacowania optymalnego cyklu produkcji brojlerów przy zastosowaniu współczynnika ekonomicznej efektywności

Przedstawiona praca wyjaśnia matematyczne metody i dostępne obecnie statystyczne techniki do ekonomicznej charakterystyki produkcji mięsa brojlerów w ekonomicznych warunkach Turcji. Opisano dotychczasowy ekonomiczny model i klasyczną metodę używaną obecnie w świecie przy podejmowaniu decyzji przez jednostki nadzorujące. Opierając się na tych ocenach, zdefiniowano potrzebę dalszych badań. Na podstawie naszych prac stwierdzono, że matematyczny model ekonomicznej optymalizacji produkcji przy zastosowaniu współczynnika ekonomicznej efektywności powinien przyczynić się do poprawy rentowności. Klasyczna metoda ekonomicznej optymalizacji produkcji zwierzęcej nie jest przydatna do wszystkich rodzajów ekonomicznych ocen; konieczne jest uwzględnienie zakresu różnych wartości tak, aby przyjęta metoda była najwłaściwsza w odniesieniu do dostępnych danych i dla charakteryzowania ekonomicznych zagadnień. W przeprowadzonych rozważaniach przyjęto następujące podstawowe dane: całkowity marginalny przychód, całkowita marginalna ilość paszy plus zbiorczy koszt kurczęcia, całkowity marginalny przychód netto, marginalne wykorzystanie paszy plus minimalny koszt kurczęcia oraz współczynnik ekonomicznej efektywności dla prowadzonych obliczeń. Na podstawie obliczonej matematycznej funkcji pomiędzy okresem produkcji a współczynnikiem ekonomicznej efektywności, oszacowano optymalny okres produkcji. Następnie oznaczono całkowity współczynnik ekonomicznej efektywności przez włączenie obliczonej funkcji matematycznej.