An econometric approach for prediction of optimal egg production period by coefficient of economic efficiency and multiphasic analysis

C. Oğuz, S. S. Parlat and K. Peker

Ein ökonometrischer Ansatz zur Vorhersage optimaler Eierproduktionsperioden mittels ökonomischem Effizienzkoeffizienten und Multiphasenanalyse

1. Introduction

The egg production of Turkey is one of the fastest growing sectors in the country. Egg farms are considered as one of the highest priority areas that have gained major support and incentives in the government policy. Egg 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 egg 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 as well as prices. 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 process (CHAVAS and ALIBER, 1993). 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 consid-

Zusammenfassung

Der gegenständliche Beitrag nützt ökonometrische Methoden und die zurzeit verfügbare Mehrphasenanalysetechnik sowie den ökonomischen Effizienzkoeffizienten zur Charakterisierung optimaler Legeperioden unter den wirtschaftlichen Rahmenbedingungen der Türkei. Beschrieben werden die gängigen ökonometrischen Modelle und klassische Methoden, wie sie gegenwärtig für politische Entscheidungen angewandt werden. Gestützt auf diesen Überblick wird künftiger Forschungsbedarf definiert. Die Arbeit lässt den Schluss zu, dass mit dem ökonomischen Effizienzkoeffizienten arbeitende mathematische Modelle der wirtschaftlich optimalen Legeperiodendauer die Wirtschaftlichkeit verbessern. Die klassische Methode der wirtschaftlichen Optimierung in der Tierproduktion taugt nicht für alle Arten der Wirtschaftlichkeitsbeurteilung. Zu erwägen sind verschiedene Ansätze, so dass die eingesetzte Methode am besten an die verfügbaren Daten und an die in Rede stehenden Wirtschaftsrisken angepasst ist. Die gegenständige Untersuchung misst als Daten zur Beurteilung: den Gesamtdeckungsbeitrag, die gesamten variablen Futter und die kumulierten Kosten für die Hühner, das gesamte Netto-Grenzkostenergebnis, die Grenzkostenrate der Futterverwertung samt Hühnergrenzkosten als Koeffizient der ökonomischen Effizienz. Nach Errechnung des mathematischen Zusammenhanges zwischen Produktionsperiode und ökonomischem Effizienzkoeffizienten wurde die optimale Produktionsdauer mittels Multiphasenanalysetechnik ermittelt. Daraus ergab sich die optimale Legeinsatzperiode mittels abgeleiteter Funktion. Der wirtschaftliche Gesamteffizienzkoeffizient wurde durch Integration der berechneten mathematischen Funktion geschätzt.

Schlagworte: Multiphasenanalyse, ökonomischer Effizienzkoeffizient, mathematisches Modell, Eierproduktion.

Summary

The present paper uses econometric methods and presently available multiphasic analysis technique and coefficient of economic efficiency to economically characterize optimal egg production period under the economic conditions of Turkey. The state-of-the-art econometric modeling 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 modeling 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 this research, used basic data for evaluation were: total marginal income, total marginal food *plus* cumulative pullet cost, total marginal net income, marginal food conversion ratio cost *plus* marginal pullet cost is coefficient of economic efficiency. After the mathematical function between production period, and coefficient of economic efficiency was calculated, the optimum production period was predicted by multiphasic analysis technique. Then, optimal egg production period was calculated *via* derivative function. Total coefficient of economic efficiency was estimated by integration of calculated mathematical function.

Key words: multiphasic analysis, coefficient of economic efficiency, mathematical model, egg production.

ered to be economically inefficient (FRASER and CORDINA, 1999). In animal production farms, estimation of optimum production cycle is very important in respect to economic production (SCOTT et al., 1982). A classic calculation method would not be more suitable for neither economic optimization assessment, nor for all databases. The classical method only takes into consideration marginal net income *minus* marginal cost without making any analysis of mathematical function between total marginal net income and marginal costs. Mathematical modeling of the production time-net income relationship would improve the economic assessment process (PARLAT et al., 1999). The optimal production period depends on realization of maximal income from unit production factor (DOLL and ORAZEM, 1984). It could be calculated realistically by 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, multiphasic functional analysis technique of production gives information about maximization of net income (KOOPS et al., 1987; AGGREY et al., 1993). 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 of 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 of econometrical models assumes 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 an optimal production time for egg producers by using a multiphasic analysis technique. Optimum production time for an animal production system can be estimated by econometric 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, optimum economic production level could be reached, when marginal cost is equal to marginal income (LOWENBERG-DEBOER, 2004).

This research was prepared given the need for a new approach to calculating of optimum egg production time with regard to compensation of various deficiencies by multiphasic analysis technique and coefficient of economic efficiency.

2. Material and Methods

2.1 Theory

The most basic assumption of a production function is that a multiphasic analysis of econometric relationship exists between production time and coefficient of economic efficiency.

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

Where y is the coefficient of economic efficiency and x_1, x_2 are vectors of production time. At the same time vectors x_1 and x_2 represent total marginal net income and marginal cost, respectively. Farms produce y output, by using two inputs (x_1, x_2). A constant return to scale production function is assumed. In general, for econometrical models, the optimal value of y depends on prices and costs of animal products. The coefficient of economic efficiency, multiphasic analysis technique and time equation gives the profit or risk-rated profit function. This function reflects the solution to the firm's optimisation problems.

Production data of a commercial egg producer farm having a total of 20.000-laying hens' capacity were used for this study. In this research, the first laying age of replacement pullet (RP) was 18 weeks. Replacement pullet cost (RPC) was $ 2,50/hen and total RPC was $ 50,000. Also food price was $ 0,032/egg and $ 0,036/egg for first two periods and other periods, respectively. In this study, main expenses were RPC and food cost as these expenses were 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 egg production (MEP), cumulative egg production (CEP), marginal food conversion ratio (MFCR), total marginal food cost (TMFC), marginal food conversion ratio cost (MFCRC), marginal hen cost (MHC) and cumulative hen cost (CHC) *per* hen for each peak period (4 periods) were calculated. Then, total marginal income (TMI), total marginal food (TMF) *plus* cumulative hen costs (CHC), total marginal net income (TMNI), marginal food conversion ratio cost *plus* marginal hen cost (MC) and coefficient of economic efficiency (CEE) *per* hen for each peak 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, econometric function between production period and (x) and CEE (y) by multiphasic analysis technique is calculated. Finally, the optimum production cycle was estimated *via* 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 derivative 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* derivative function is mathematically the optimum production time (ABRAMOWITZ and STEGUN, 1972). By using the calculated x value for $f(x)$ the marginal CEE value for optimum production time could be esti-

Table 1: Marginal food intake, marginal egg production, cumulative egg production, marginal food conversion ratio, total marginal food cost, marginal food conversion ratio cost, marginal hen cost and cumulative chick cost per chick for each period

Tabelle 1: Grenzfutteraufnahme, Grenzlegeproduktivität, kumulierte Legeproduktivität, Grenzfutterverwertung, gesamte Grenzfutterkosten, Grenzfutterverwertungskosten, Grenzhühnerkosten und kumulative Hühnerkosten pro Henne und Legeperiode

Period week	Marginal food intake kg/ period	Marginal egg production kg/hen/ period	Cumulative egg production egg/period	Marginal food conversion ratio (FCR) kg/egg/period	Total marginal food cost $/period	Marginal FCR cost $/period	Marginal food plus replacement pullet cost $/egg	Marjinal replacement pullet cost ($/egg)	Marjinal pullet cost per marginal egg production ($/hen/egg production)	Cumulative replacement pullet cost ($/egg)
10	123,200	0,664	929.600	0,024	0,03591	0,132	0,0780	0,054	0,0177	0,054
20	144,200	0,916	2.212.000	0,020	0,03051	0,112	0,0430	0,077	0,0103	0,077
30	146,650	0,875	3.437.000	0,021	0,03240	0,119	0,0360	0,092	0,0063	0,092
40	147,420	0,830	4.599.000	0,023	0,03429	0,126	0,0340	0,103	0,0045	0,103
50	148,260	0,773	5.681.200	0,025	0,03699	0,137	0,0340	0,112	0,0034	0,112
60	133,840	0,671	6.622.000	0,025	0,03834	0,142	0,0330	0,120	0,0025	0,120
70	149,100	0,725	7.637.000	0,026	0,03969	0,147	0,0330	0,127	0,0023	0,127
80	149,100	0,691	8.604.400	0,028	0,04158	0,154	0,0340	0,133	0,0020	0,133

Table 2: Total marginal income, total marginal food plus cumulative chick costs, total marginal net income, marginal food conversion ratio plus marginal chick costs and coefficient of economic efficiency per chick for each period

Tabelle 2: Gesamtdeckungsbeitrag, gesamt Futtergrenzkosten samt kumulativen Hühnerkosten, Gesamtnettogrenzeinkommen, Grenzrate der Futterverwertung samt Grenzkosten für Hühner sowie der wirtschaftliche Effizienzkoeffizient pro Henne für jede Legeperiode

Period week	Total marginal income $/period	Mrj Pullet cost + Mrj Food cost ($/hen/egg/period)	Total Mrj net income $/hen/egg/period	Marginal FCR *plus* Mrj pullet cost ($/period)	Coefficient of economic efficiency
10	0,0212	0,0334	-0,0122	0,1497	-0,084
20	0,0293	0,0286	0,0007	0,1223	0,0057
30	0,0280	0,0250	0,0300	0,1253	1,2394
40	0,0265	0,0233	0,2417	0,1305	1,852
50	0,0247	0,0223	0,2247	0,1404	1,600
60	0,0214	0,0195	0,0019	0,1445	0,1314
70	0,0232	0,0213	0,2107	0,1493	1,4112
80	0,0221	0,0210	0,0011	0,1560	0,0070

mated. 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) softwares.

2.2 Numerical example and practical implication of multiphasic analysis of econometric function

Marginal food intake (MFI), marginal egg production (MEP), cumulative egg production (CEP), marginal food conversion ratio (MFCR), total marginal food cost (TMFC), marginal food conversion ratio cost (MFCRC), marginal hen cost (MHC) and cumulative hen cost (CHC) *per* hen for each peak period are shown in Table 1. CHC *per* hen for each peak period was calculated as follows:

CHC of 1st period (CHC_1) = (hen cost / CEP)*MEP of 1st period (MEP_1)

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

MNI *per hen* for each period were calculated with the Figures from Table 1 and Table 2. MNI *per* hen for each peak period was calculated as:

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

Finally, CEE *per* hen for each period was calculated as follows:

CEE *per* hen of 1st period (CEE_1) = TMNI *per* hen of 1st period ($TMNI_1$) / MC *per* hen of 1st period (MC_1)

The multiphasic analysis of econometric function was calculated to determine the relationship between *x* and *y* (cal-

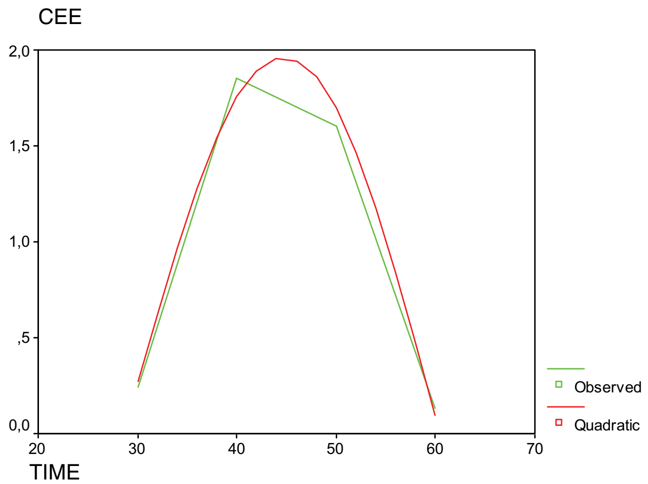

Figure 1: Graph of relationship between production period (X) and coefficient of economic efficiency (Y)

Abbildung 1: Graphische Darstellung des Zusammenhanges zwischen Legeperiode (X) und wirtschaftlichem Effizienzkoeffizienten (Y)

culations were based on data from 30th to 60th week). The relationship between *x* and *y* was shown in Figure 1. The estimated regression equation, coefficient of determination and variance analysis of relationship between *x* and *y* were shown in Table 3. The mathematical function between *x* and *y* is as follows:

$$y = f(x) = -13,42 + 0,6875X - 0,0077X^2$$

Where;

y is CEE (dependent variable)
x is 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

Tabelle 3: Geschätzte Regressionsgleichung, Bestimmtheitsmaß und Varianzanalyse für den Zusammenhang zwischen Legeperiode und wirtschaftlichem Effizienzkoeffizienten

Source	SS	df	MS	F	P
Regression	2.3900	2	1.1950	56.9187	0.0933
Residuals	0.0209	1	0.0209	0.0209	

Estimated regression equation[a]: $Y = -13.4208 + 0.6875x - 0.0077x^2$
Determination of coefficient: $R^2 = 0{,}97391 \pm 0.1449$

[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;

$$y' = f'(x) = dy/dx = -0{,}6875 - 0{,}0154X$$

When this function is solved, *x* is calculated as 44,64 weeks. That is, optimal production period is 44,64 weeks for the present study. By using calculated x_{value} in the *f(x)* function, maximum CEE values during production period were obtained as:

$f(44{,}64) = 1{,}925$ (maximum CEE value)

As seen from Table 2, CEE for 44,64 weeks was maximum. Also, total CEE *per* chick could be calculated by integration of *f(x)* function from 30[th] to 44.64[th] week. That is;

$$\int_{30}^{44.64} f(x) = \int_{30}^{44.64} -13.42X + 0.34375X^2 - 0.0026X^3 = 18.0728$$

3. Results and Discussion

Estimated coefficients are highly significant (Table 3). These results reveal substantial inefficiencies in egg production in the central region of Turkey. By this measure, this farm could reduce its cost without reducing its output when CEE is considered for economic optimization. The economic efficiency for a sample of an egg farmer was determined by the econometric approach including the estimation of input-oriented mathematical model. Greater differences in economic values were observed when economic values were compared based on econometric optimization model. Generally, the difference in optimal values of the management variable depends on market, economic and environmental conditions in specific commercial egg operations. The example is very simplified, with only one output and one input variable, but does illustrate that econometrical models can have a large impact on economic profitability. There are great differences between traditional calculations and econometrical functions. From the economic point of view, production functions represent a better model of real economic situation and producer's choices. Marginal economic production of any factor could be realized when factor cost is equal to product price. The results of this study are in agreement with other explanations of functional analysis of production (HEADY, 1968; DOLL et al., 1968; CRAMER and CLARENCE, 1979). This also means that a significant proportion of egg 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 the 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 egg production in the region. It may be appropriate to implent training programs for the producers of laying egg farms with a goal of improving economic efficiency. Additional research will be necessary to determine the comprehensive consequences of the methods of efficient egg production.

The purpose of this study was to contribute to the evaluation of the performance of economic egg production under the economic conditions of Turkey. This study generated estimates of an econometric production function for an egg farm in the central region of Turkey. A classic calculation method would not be suitable for economic optimization assessment, or for all databases. Mathematical modeling 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.

4. Conclusions

It is apparent that optimum production period for this study is 44,64 weeks. The method makes possible to calculate economically optimum production period in egg farms. This model should be evaluated as an 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.

References

ABRAMOWITZ, M. and I. A. STEGUN (1972): Handbook of Mathematical Functions. Dover Publ. New York.

AGGREY, S. E., C.R. NICHOLS and K. M. CHENG (1993): Multiphasic analysis of egg production in Japanese quail. Poult Sci. 72, 2185–2192.

BANKER, R. D., A. CHARNES and W. W. COOPER (1984): Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science 30, 1078–1092.

CHAVAS, J. P. and M. ALIBER (1993): An analysis of economic efficiency in agricultural: A non-parametric approach. J. Agr. Resour. Econ. 18, 1–16.

CRAMER, G. L. and W. J. CLARENCE (1979): Agricultural Economics and Agribusiness. John Wiley Publ. New York.

DEBERTIN, D. L. (1986): Agricultural Production Economics. Macmillan Publishing Company, New York.

DOLL, J. P., J. V. RHODES and G. J. WEST (1968): Economics of Agricultural Production. Irwin Publ. Illinois.

DOLL, J. P. and F. ORAZEM (1984): Productions Economics. John Wiley Publ. New York.

FRASER, I. and D. CORDINA (1999): An application of data envelopment analysis to irrigated dairy farms in Northern Victoria, Australia. Agri Systems 59, 267–282.

GROEN, A. (1989): Cattle breeding goals and production circumstances. PhD Thesis, Department of Management of Animal Breeding, Wageningen Agricultural University, Wageningen.

HARDAKER, J. B., R. B. M. HUIRNE and J. R. ANDERSON (1997): Coping with risk in agriculture. CAB International, Biddles Ltd, Guilford.

HIROOKA, H. and Y. SASAKI (1998): Derivation of economic weights for carcass traits in Japanese Black cattle from field records. J. Anim. Breed. Genet. 115, 27–37.

KOOPS, W. J., M. GROSSMAN and E. MIGHALSKA (1987): Multiphasic growth curve analysis in mice. Growth 51, 372–382.

LOWENBERG-DEBOER, J. (2004): Economics of precision agriculture. Site-specific Management Center, Purdue University (http://www.precisionag.org).

MINITAB (1995): Minitab Inc. State Coll. PA, 16801 (USA).

PARLAT, S. S., A. O. YILDIZ and I. YILDIRIM (1999): A mathematical model for estimation of fattening period by coefficient of fattening efficiency in meat type Pekin ducks. 12th European Symposium on Waterfowl. Adana, (Turkey), 165.

SCOTT, M. L., M. C. NESHEIM and R. J. YOUNG (1982): Nutrition of the Chicken. M. L. Scott & Associates Publ. Ithaca, New York.

SPSS (1988): SPSS/PC+V.2.0. Base Manuel for the IBM PC/XT/AT and PS/2. Marija and Morusis, SPSS Inc.

STEEL, R. G. D. and J. H. TORRIE (1980): Principles and Procedures of Statistics. A Biometrical Approach. McGraw-Hill Book Co., New York.

WILTON, J. W. and M. F. GODDARD (1996): Selection for carcass and feedlot traits considering alternative slaughter end points and optimised management. J. Anim. Sci. 74, 37–45.

Address of authors

C. Oğuz and K. Peker, Department of Agricultural Economics, Agricultural Faculty, Selçuk University, 42031 Konya-Turkey

S. S. Parlat, Department of Animal Science, Agricultural Faculty, Selçuk University, 42031 Konya-Turkey

Eingelangt am 7. Jänner 2003

Angenommen am 21. Mai 2003