Measuring productivity of production factors in broiler breeding industry using fuzzy regression

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Abstract To calculate partial and total productivity of production factors in broiler farms in Yazd province, 72 manufacturing units were selected based on simple random sampling method and their information and statistics were collected for one production period in the second half of 2013. To measure productivity, the Cobb-Douglas production function was estimated using classic and fuzzy regression methods. Workforce and energy had significant positive effects on broiler meat production. Feed had the highest coefficient (0.71 in the classic regression and 0.58 in fuzzy regression) and was the most effective production factor. Partial productivity of all variables and total production factors were also calculated. Productivity of total production factors was 1.90 in classic regression; concerning fuzzy regression with confidence interval of 90%, upper and lower bounds were 2.86 and 1.37 respectively.

Keywords: productivity, production function, broiler, fuzzy regression

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Introduction

Producing over one million tons of chicken meat, broiler and poultry industry has an important role in providing the protein needed in Iran. Concerning the changes that have occurred in Iran's poultry industry over the last three decades, chicken meat has become an essential household item and one of the most important sources of protein (Azarbaijani et al., 2009). Moreover, this industry has a significant benefit for micro owners. In addition, it plays an important role in improving occupational opportunities and production of foodstuff (Regmy, 2001; Dashti et al., 2011). Despite a quantitative increase in chicken farms over the past years, it seems that chicken meat production has not increased dramatically due to several reasons including breeding quality and inefficient use of the related production resources. That is, amount of production, number of poultry and carcass average weight suggest that the major problem in the third world countries is not in the number of poultry farms but rather in low productivity of production factors, productivity of production units, poor management, ignoring economy principles, lack of understanding factors affecting the production and their relative importance, shortage of appropriate studies, improper market system, fluctuations in the price of inputs, outputs and health issues (Asfanjari Konari, 2011). Farooq et al. (2013) carried out an economy study of scale in broiler arming in Khyber Pakhtunkhwa. In this study Farm size was randomly classified on the basis of number of poultry birds per flock and the empirical results indicate that on average poultry farmers raised 4.97 flocks per year. Pourkand and Moetamed (2011) analyzed production productivity of broiler units in Gilan Province in 2009-10. Using the data from 50 active aviaries across Gilan province and the logarithmic function of production, they showed that among the contributing factors on poultry production, feed was the most influential, and the technical efficiency of the units was reported at 90%.

Hajirahimi and Karimi (2009) carried out an economy study and evaluated the productivity of production factors in broiler farms in 70 manufacturing units in Kurdistan based on random sampling method. Their results showed that mean productivity of average feed consumed in the studied farms was 0.54 and the average total productivity for the studied data was 3.92. Mohaddes and Mazhari (2008) examined the total factor productivity of aviculture industry in South Khorasan Province. Using cross-sectional data of 150 farmers in South Khorasan Province and random sampling, they calculated the marginal production of feed and total factors productivity at 0.4 and 1.07, respectively. Mohammadi Nejad et al., (2008) compared the performance of broiler breeding units in different provinces of Iran. Their results indicated that total productivity of this industry had an average growth of 4.6% for the years 1990-96. They emphasize that to improve the productivity of production resources of aviaries and to be able to present scientific plans for boosting productivity, the first step is measuring and determining productivity.

The purpose of this study is to measure the productivity of broiler chicken production using both classic and fuzzy regression models.

Materials and Methods

Generally speaking, one of the easiest and commonest definitions of productivity is the ratio of output to input. In other words, ratio of outputs to inputs means:

$$\text{Productivity} = \text{output}/\text{input} \quad (1)$$

In addition to its general definition, partial and total productivity of production factors must also be explained. Therefore, partial productivity is the ratio of output(Y) to one of inputs(x_i, i=1,...,n); that is, partial productivity is average production of every production input (AP_{xi}) (Hajirahimi and Karimi, 2009)

$$AP_{xi} = Y/xi \quad (2)$$

Total productivity of production factors is productivity of all factors or ratio of total output to all consumed resources. Total productivity scale explains all resources and factors consumed to create the output and are calculated as follows:

Total productivity index of production factors (TFP):

$$TFP = TR/\Sigma w_i c_i \quad (3)$$

where, TR is total value received in the i^{th} unit, C_i is i^{th} input expense in i^{th} unit, W_i is average i^{th} input expense share in total expense of units.

In econometric methods, productivity is calculated through estimating a production function. Therefore, to select the type of broiler production function, the information was extracted from the questionnaires and types of production functions were estimated; based on the properties of a good model, among other functions (rational explanatory variables, adaptability of the theory, model clarification, detectability, generalizability and F test), the Cobb-Douglas function was selected (Gojarati, 2002).

To estimate the production function in which the per capita production of a chicken (in terms of a kilogram of a living chicken) was related to its effective factors, all factors (as model independent variables) affecting per capita production of broiler meat were taken into consideration; finally, three important and effective factors were recognized as the final independent variables using the backward selection method. Concerning Cobb-Douglas function, the final model was (Pourkand and Moetamed, 2011):

$$Y_i = A x_1^{\beta 1} x_2^{\beta 2} x_3^{\beta 3} \quad (4)$$

After applying the logarithm to both sides, we have:

$$LnY_i = Ln\, A + \beta_1 Lnx_1 + \beta_2 Lnx_2 + \beta_3 Lnx_3 \quad (5)$$

Y_i : is per capita production of chicken meat in kg, X_1: is per capita consumed feed per every chicken in kg, X_2: is per capita energy cost per every chicken in Rials, X_3: is per capita workforce (hour/person) per chicken, A: is intercept. To estimate production function parameters, cross-sectional statistics and ordinary least squares (OLS) method were used. After production function was calculated using classic linear regression, fuzzy liner regression was used to evaluate production function.

In classic regression model:

$$Y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \qquad \varepsilon_i = 1, 2, \ldots, n \quad (6)$$

it is assumed that ε_i is independent and has normal distribution: $N(0,\sigma^2)$ (σ^2 is unknown).

Thus, the classic regression considers some assumptions about errors probable distribution. Although the classic linear regression model has several applications, it is sometimes hard to make this model. Insufficient or low number of observations, problems in defining an appropriate distribution function, ambiguity in the relationship between dependent and independent variables, ambiguity in occurrence or level of occurrence of events, and carelessness and error are some of the problems found in making this model. To solve these problems, fuzzy linear regression method may be used (Sadati Nejad et al., 2011; Chang and Ayyub, 2001; Tanaka and Ishibuchi, 1995).

Fuzzy linear regression

In the classic linear regression, a specific amount of an output variable is calculated for each set of input variables; however, the fuzzy regression estimates a range of possible amounts for the output variable. Distribution of these amounts is determined as membership function (Tanaka et al., 1982). This model obtains best regression equation by minimizing fuzzy amounts. It is done by minimizing total width of membership functions of fuzzy coefficients of regression equation. One of regres sion models is possibilistic regression model in which coefficients are fuzzy while inputs and outputs are non-fuzzy. In this study, this model was used based on the nature of data (equation 4) (Sadatinejad et al., 2011; Khashei and Bijari, 2010 ;Tanaka and Ishibuchi, 1995).

$$\tilde{y}=\widetilde{A_0}+\widetilde{A_1}x_1+\widetilde{A_2}x_2+\widetilde{A_3}x_3+\ldots+\widetilde{A_n}x_n \quad (7)$$

Coefficients of the above equation ($\tilde{A}_0, \tilde{A}_1, \tilde{A}_2, \ldots, \tilde{A}_n$) are fuzzy numbers and input variables ($x_1, x_2, \ldots, x_n$) are normal numbers. For every "n" variable, one fuzzy number like $\tilde{y}$ is calculated as the output. Suppose that there are

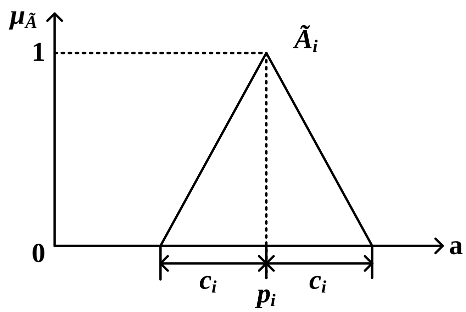

Fig. 1. Membership function of fuzzy coefficients

m rows of observational data, and there are n input variables (X_{ij}) and an output variable in every row. Also, suppose that the fuzzy number is in the form of a symmetrical triangle (fig. 1: c_i is number width and P_i is center of fuzzy number). In this case, membership function can be written as the equation 8:

$$\mu_{\tilde{A}}(a_i)=\begin{cases} 1-(|P_i-a_i|/C_i) & P_i-C_i\leq a_i\leq P_i+C_i \\ 0 & \end{cases} \quad (8)$$

Fuzzy number $\tilde{A}$ in Fig. 1 shows toughly equal amount of P_i and C_i shows its fuzzy amount; this can be shown as $(P_i, C_i)\widetilde{A_1}$. Therefore, fuzzy regression equation is as follows:

$$\tilde{y}=(P_0,C_0)+(P_1,C_1)x_1+(P_2,C_2)x_2+\ldots+(P_n,C_n)x_n \quad (9)$$

Membership function of output fuzzy variable ($\tilde{y}$) is shown as follows:

$$\mu_{\tilde{y}}(y)=\begin{cases} max\left(min\left[\mu_{\tilde{A}}(a_i)\right]\right) & \{a|y=f(x,a)\neq\emptyset\} \\ 0 & \end{cases} \quad (10)$$

Inserting equation 8 in equation 10, equation 11 is obtained

$$\mu_{\tilde{y}}(y)=\begin{cases} 1-\frac{y-P_0-\sum_1^n P_iX_i}{C_0-\sum_1^n C_i|X_i|} & X_i\neq 0 \\ 1 & X_i=0, y=0 \\ 0 & X_i=0, y\neq 0 \end{cases} \quad (11)$$

Different methods have been proposed to solve fuzzy linear regression problems. One of them is to change fuzzy linear regression problem to a linear programming problem. The aim of fuzzy regression model is to determine optimal amounts of $\tilde{A}$ in a way that membership degree of fuzzy output variable (for all data) is bigger than a certain amount (such as h) which is determined by the user. In other words, for "m" rows of data, (j=1, 2, 3, 4,…,m), the following inequality must hold:

$$\mu_{\tilde{y}j}(y_i)\geq h \quad (12)$$

As the amount of h increases, fuzzy amounts of outputs increase too. Equation 12 shows that the fuzzy output must be between the amounts of A and B shown in figure 2. According to equation 9, center and width of output membership function equal $c_0+\sum c_iX_i$, $P_0+\sum_1^n P_iX_i$. In fuzzy possibilistic regression, coefficients are determined in a way that width of the fuzzy output is minimized for all data sets. According to the above issues, the objective function and constraints of linear programming problem can be presented as in equations 13 to 16.

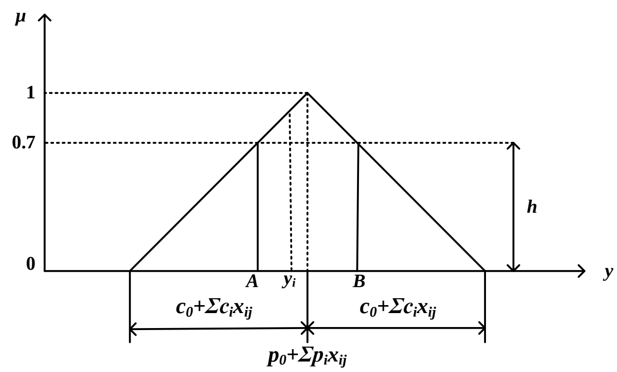

Fig. 2. Fuzzy output membership function

Constraints of the problem were obtained by inserting the equation 8 in the equation 12. Thus, to solve linear regression problem with fuzzy coefficients and non-fuzzy data, the only thing we must do is to solve a linear programming model based on the above equations. Equations 15 and 16 are written separately for each pair of observational data. Hence, 2m inequalities are formed based on the above-mentioned equations. Therefore, the required data enters into the program and the inequalities are formed. The obtained inequalities are then solved by Lingo software and finally the output of this program is the coefficient "P" (Sadatinejad et al., 2011; Tanaka and Ishibuchi, 1995).

$$\tilde{y}=\widetilde{A_0}+\widetilde{A_1}x_1+\widetilde{A_2}x_2+\widetilde{A_3}x_3+\ldots+\widetilde{A_n}x_n \quad (13)$$

$$Minimize: mc_0+\sum_{j=1}^m\sum_{i=1}^n C_i\left|X_{ij}\right| \quad (14)$$

$$P_0+\sum P_iX_{ij}-(1-h)\left[C_0+\sum c_iX_{ij}\right]\leq y_j \quad (15)$$

$$P_0+\sum P_i X_{ij} +(1-h)\left[C_0+\sum c_i X_{ij}\right]\geq y_j \qquad (16)$$

The population consisted of all active broiler farms in Yazd province. According to the statistics reported by the Agricultural Jihad Organization of Yazd province, there were 516 farms in Yazd in 2013. Owing to limitations in time and expenses, 72 farms were selected using random sampling method. After questionnaires were completed, data was processed using Excel, Eviews and Lingo software and production function was estimated. Finally, classic and fuzzy regression methods were used to calculate and compare partial and total productivity of production factors.

Results and Discussion

The results of analysis of data collected using classic linear regression (estimation of equation 5) are presented in Table 1.

The R^2 values show that 71% of the variance in chicken meat production have been explained by three feed, energy and workforce. Feed had the highest coefficient (0.71) on broiler production; it shows a high ratio of production to feed variable.

The energy coefficient is low which reflects unsuitable conditions of chicken farm buildings, equipment, installations and management; workforce coefficient is 0.13. Since the Cobb-Douglas function was used here, coefficients are production elasticity of inputs or sensitivity of production to inputs. In the Cobb-Douglas function, the ratio of output to scale is equal to sum of production tendencies to variable inputs. Total production elasticity of 0.896, which was between zero and one, reflected output to descending scale of the studied chicken farms; that is, as input consumption increased by 10%, meat production increased by less than 10%. After production function was evaluated using the classic regression method, it was also (equation 2) evaluated by fuzzy linear regression (Table 2).

Calculated coefficients (Table 2) are in the form of fuzzy numbers which include center and width or coefficient uncertainty amount. Coefficients whose bandwidth is zero (upper and lower bounds have the same numbers) show certainty in calculating the coefficients, and the obtained fuzzy numbers are equal to a definite number; feed and energy were definite in h=0.1. Concerning the variable "workforce", however, there is an uncertainty, and two different coefficients were evaluated for upper and lower bounds. Coefficients obtained by fuzzy regression model also revealed high effect of the variable "feed" (0.58) on the production of chicken meat. Also, the variables "consumed energy and workforce" had positive effects on production of chicken meat in the studied chicken farms.

Table 1. Results of classic linear regression of production function of chicken farms

Variable	Regression Coefficient
0.71***	X_1
0.06**	X_2
0.13**	X_3
0.17*	C
0.71	R^2

X_1: feed, X_2: energy, X_3: workforce, C: intercept.
* P < 0.1, ** P < 0.05 and *** P < 0.01.

Table 2. Results of fuzzy linear regression of production function of chicken farms

Variable	h=0/1	
	Upper bounds	Lower bounds
X_1	0.58	0.58
X_2	0.13	0.13
X_3	0.20	0.20
C	0.41	-0.41

X_1: feed, X_2: energy, X_3: workforce, C: intercept.

Per capita consumption of poultry meat in Iran was about 25.4 kilograms in 2013/2014, indicative of a 13 percent increase over the past six years. In other words, since 2008, the average per capita consumption of poultry meat has increased by 3 kilograms (The Bureau of Statistics, USA Department of Agriculture, 2014). Population growth and low cost of poultry meat, as compared to other types of meat, is the reason for the growth in its domestic consumption.

Partial and total productivity of production factors were measured in both fuzzy and classic methods and results are shown in tables 3 and 4.

Mean productivity of average feed consumed for the studied chicken farms was 0.46 using the classic regression. That is, 0.46 kg of live chicken was produced per kg of feed consumed. This is the feed efficiency which is opposite of the feed-to-meat conversion ratio of 2.2 in the studied units. The findings are in agreement with those of Hajirahimi and Karimi (2009) and Pourkand and Moetamed (2011).

Using fuzzy regression method, the mean productivity of average feed was 0.7 and 0.33 for upper and lower bounds, with the conversion coefficients of 1.42 and 3.03

Table 3. Partial and total productivity of factors using results of classic linear regression

Variable	Partial productivity
X1	0.46
X2	0.006
X3	0.40
Productivity of total production factors	1.90

X_1: feed, X_2: energy, X_3: workforce.

Table 4. Partial and total productivity of factors using results of fuzzy regression

Variable	Partial productivity in h=0/1	
	Upper bounds	Lower bounds
X1	0.70	0.33
X2	0.01	0.004
X3	9.30	4.60
Productivity of total production factors	2.86	1.37

X_1: feed, X_2: energy, X_3: workforce.

3.03, respectively. Globally, conversion coefficient is under 2; concerning the above results, broiler units can optimally produce meat in the upper bound. Mean productivity of average workforce was 6.39; therefore 6.39 kg live chicken was produced per hour workforce. Mean productivity of average workforce was 9.30 and 4.60 for the upper and lower bounds, respectively. Concerning energy, the average productivity was 0.0068 in the classic regression model and h=0.1 in the fuzzy regression model. Its partial productivity was 0.01 and 0.004 for the upper and lower bounds, respectively. Because the partial productivity of each production factor is calculated by keeping other factors constant, no clear result or image of the performance of the units can be obtained. To solve this problem, total productivity of factors was calculated by the equation1; it was 1.90 in the classic regression method and 2.86 and 1.37 in the fuzzy regression method. These values show that 1.90 units of income were earned by the owners for every expense unit in the classic model (in the fuzzy regression method, 2.86 and 1.37 in upper and lower bounds, respectively). Comparing the results of classic and fuzzy regression methods, it can be said that both methods had similar results. The only difference was that the fuzzy regression method lacks the restricting assumptions especially when distribution of residuals is not normal (Fig 3). In addition, as the results show, classic regression is in the confidence interval of the fuzzy regression (h= 0.1) and thus results are more reliable.

Also, applying fuzzy linear regression seems more reasonable in small samples due to unreliability of the assumptions of the classic regression model.

Conclusions

When productivity of production factors is low, determining productivity of inputs and increasing them can prevent loss of resources and reduce average production costs. As profit increases, production motives increase too. Thus, to determine the existing conditions of chicken farms, it is essential to measure partial and total productivity of production factors. There was a significant difference between the upper and lower bounds of productivity; therefore, it is possible to raise productivity in the studied chicken farms to increase poultry meat production in Iran. Also, to increase the productivity of the said farms, it is suggested that units with higher productivity be recognized and presented as the model for input consumption, management and other conditions. In this case, productivity of other chicken farms will increase and the best chicken farms will also increase their productivity; agricultural experts can play an important role in this regard.

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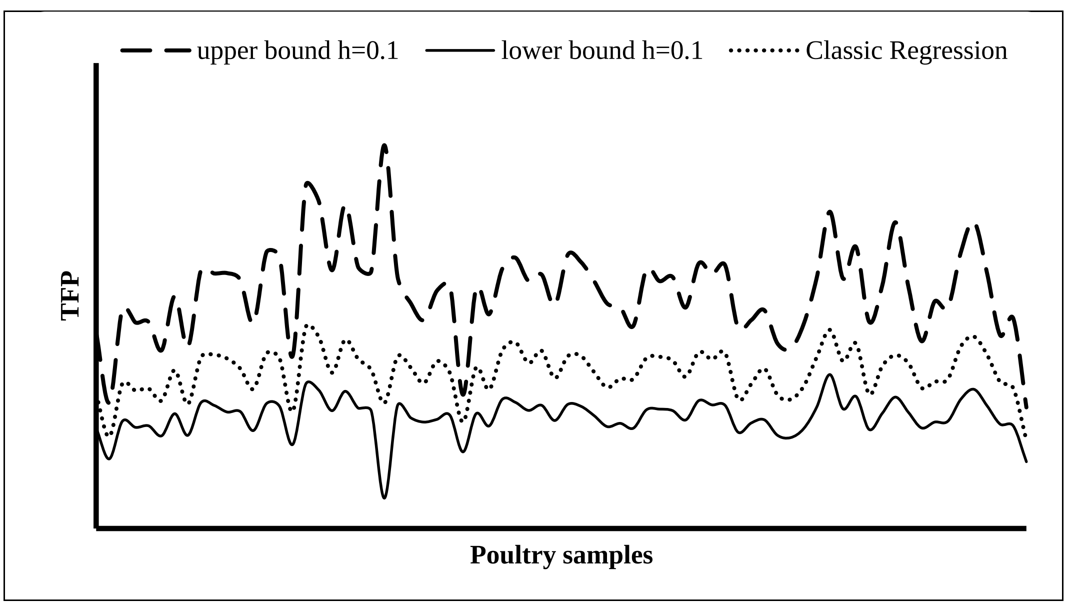

Fig. 3. TFP, using Classic and fuzzy regression

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اندازه گیری بهره وری عوامل تولید صنعت پرورش مرغ گوشتی با استفاده از رگرسیون فازی

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چکیده جهت محاسبه بهره وری جزئی و بهره وری کل عوامل تولید در مرغداری های گوشتی استان یزد، ۷۲ واحد تولیدی بر اساس روش نمونه گیری تصادفی ساده انتخاب و آمار و اطلاعات آن‌ها برای یک دوره تولید در شش ماه دوم سال ۱۳۹۲ جمع آوری شده است. برای اندازه گیری بهره‌وری، تابع تولید کاب داگلاس با استفاده از روش‌های رگرسیون و رگرسیون فازی برآورد گردید. نیروی کار و انرژی، تاثیر مثبت معنی دار بر تولید گوشت مرغ در دوره مورد بررسی داشته اند و نهاده دان با داشتن بالاترین ضریب (۰/۷۱ در رگرسیون کلاسیک و ۰/۵۸ در رگرسیون فازی) موثرترین عامل تولید بوده است. سرانجام بهره وری جزئی نهاده ها و کل عوامل تولید با استفاده از روش های رگرسیون کلاسیک و فازی محاسبه گردید که بهره وری کل عوامل تولید در روش رگرسیون کلاسیک ۱/۹۰ و در روش رگرسیون فازی با (h=0.1) فاصله اطمینان ۹۰ درصد در کران بالا و پائین به ترتیب ۲/۸۶ و ۱/۳۷ به دست آمده است.