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An empirical method to measure the relative efficiency of dairy producers using deterministic frontier analysis

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A R T I C L E I N F O

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A B S T R A C T

The purpose of this paper is to measure the relative efficiencies of various cow husbandries. The proposed model of this paper uses deterministic frontier analysis to measure the performance of different units responsible for taking care of cows. We gather the necessary information of all units including number of cows, amount of internet usage, number of subunits for taking care of cows, amount of forage produced in each province for grazing livestock and average hour per person training courses as independent variables and consider the amount of produced milk as dependent variable. The necessary information are collected from all available units located in different provinces of Iran and the production function is estimated using a linear programming model. The results indicate that the capital city of Iran, Tehran, holds the highest technical efficiency, the lowest efficiency belongs to province of Ilam and other provinces mostly performs poorly.

1. Introduction

Milk is one of the necessary foods in the basket of anyone in the world since it contains the necessary minerals required by human body such as Calcium. There are several dairy products built from milk and it plays an important role on people's daily food. The important issue is that this industry in Iran heavily depends on government's regulation and there is an increasing competition among all active units. One alternative to help this industry is to encourage them to increase their efficiencies by optimally using their resources. In other words, the local government knows well that any increase on milk price could easily hike inflation rate and they do not let milk producers increase their rates. An alternative solution is to provide low rate loans to help them restructure their businesses and lower their expenses. There are normally different techniques for measuring the relative efficiency of different similar units but most of them use some inputs and/or outputs to perform such analysis. We can divide them into two different techniques of parametric and non-parametric methods as follows,

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1. Parametric methods: These methods are based on the econometric estimation of the cost of production function, which needs the definition of *a priori* of the functional form of the efficient frontier and a good example of such method is stochastic frontier analysis (SFA) introduced by F□re et al. (1993). The method has been widely used among many practitioners (Coelli et al., 2005). The other technique is distribution free approach for measuring the relative efficiency of different units (Berger, 1993, Troutt et al., 2005). There is also another technique called determinitic frontier analysis (DFA) developed by Aigner et al. (1977). They estimated a deterministic frontier production function using Cobb-Douglas production function.
2. Non-parametric methods: These methods are based on mathematical programming approaches. In this case the relative efficiency of similar farms is determined based on the implementation of linear programming techniques and a good example of this technique includes data envelopment analysis (DEA) introduced by Charnes et al. (1978, 1994).

There are many real-world case studies, where different parametric and non-parametric methods are used to measure the relative efficiency of various units (Roghanian & Foroughi, 2010). Sedik et al. (1999) considered how Russian corporate farm efficiency had changed during the years from 1991 to 1995. According the their studies, Efficiency scores can be explained by several economic and institutional factors, including farm size, softness of the budget constraint, deterioration in farm terms of trade and oblast-level specialization of production.

Dios-Palomares and Martínez-Paz (2011) studied the level of technical efficiency in the olive oil industry from a multi-output perspective, and examined olive oil production in terms of quantitative and qualitative figures. They measured the relative technical efficiency indices and set specific efficiency indices for both the quality of the oil produced and the environmental influences of the production process. Iribarren et al. (2011) used life cycle assessment and DEA method for measuring the relative efficiency of farm units and reported that they could reduce up to 38% for input consumption levels, leading to impact reductions above 20% for every environmental impact category. Dimara et al. (2008) investigated the effects of productive efficiency on the survival of factories in the Greek food sector. Technical and scale efficiency scores were computed within a DEA method and were used as explanatory variables in a parametric (Weibull) survival model. They reported that high technical efficiency could increase the median survival time and it could lower the hazard rate of exit. They also reported that the effects of technical and scale efficiency on the survival of firms in the food sector are of particular relevance to food policy makers.

In this paper, we present an empirical analysis to measure the relative efficiency of various cow husbandries using deterministic frontier analysis (DFA). This paper first presents the problem statement of the proposed model in section 2 and section 3 presents the experimental results for a real-world case study. Finally, concluding remarks are given in the last to summarize the contribution of the paper.

2. Problem statement

Deterministic frontier analysis (DFA) uses a simple implementation of Cobb–Douglas function (Houthakker, 1955) as follows,

$$\ln Y_i = \sum_{i=1}^{m} \beta_i X_{ij} - \varepsilon_i, \quad j = 1, \cdots, n \qquad (1)$$

where X_{ij} represent all independent factors affecting the efficiency of the production, β_i represent the coefficients to be estimated, $\ln Y_i$ is the log of production function and ε_i is the error term. According to Eq. (1) $\ln Y_i$ is maximized when $\ln Y_i = \ln \hat{Y}_i$. Therefore, we could minimize the error term through the following linear programming problem,

$$\min \sum_{j=1}^{m} \varepsilon_i$$

subject to (2)

$$\ln \hat{Y}_i \geq \ln Y_i .$$

In model (2) we can replace $\sum_{j=1}^{m} \varepsilon_i$ from Eq. (1), which yields the following linear programming model,

$$\min \beta_0 X_0 + \cdots \beta_m X_m$$

subject to (3)

$$\beta_0 X_{01} + \cdots + \beta_m X_{m1}$$

$$\vdots$$

$$\beta_0 X_{0n} + \cdots + \beta_m X_{mn}$$

The optimal solution of Eq. (3) yields $\hat{Y}_i$ and could help calculate technical efficiency (TE) by $TE = \frac{Y_j}{\hat{Y}_j}$

3. Case study

The proposed study of this paper uses number of cows, amount of internet usage, number of subunits for taking care of cows, amount of forage produced in each province for grazing livestock and average hour per person training courses as independent variables and consider the amount of produced milk as dependent variable. In our study, all numbers are gathered from different provinces of Iran and Table 1 summarizes all the input information.

Table 1
The input information of the proposed model

Province	MP	NoS	NoC	AIU	AFP	TLU	ln MP	ln NoS	ln NoC	ln AIU	ln AFP	ln TLU
1.East Azarbayjan	2070000	4	495	20	598	10	12.24	1.39	6.20	3	6.39	2.3
2.West Azarbayjan	978910	29	1299	6	610	93	13.79	3.37	7.17	1079	6.41	4.53
3. Ardebil	193170	13	476	1	238	10	12.17	2.57	6.17	0	5.47	2.3
4. Esfahan	2521900	23	2724	3	465	10	14.74	3.14	7.91	1.1	6.14	2.3
5. Ilam	172400	6	389	8	181	191	12.06	1.79	5.99	2.08	5.2	5.25
6. Tehran	9988420	21	5841	50	75	21	16.12	3.04	8.67	3.91	4.32	3.04
7. Bakhtiari	330500	12	634	1	78	205	12.71	2.49	6.45	0	4.36	5.32
8. South Khorasan	279000	2	510	1	284	234	12.54	0.69	6.23	0	5.65	5.46
9. Razavi Khorasan	5169550	41	5692	51	284	258	15.46	3.71	8.65	3.93	5.65	5.55
10. North Khorasan	399850	10	513	1	284	346	12.89	2.30	6.24	0	5.65	5.85
11. Khozestan	124400	1	30	60	223	10	11.73	0	3.40	4.09	5.41	2.3
12. Zanjan	137800	3	206	4	138	81	11.83	1.09	5.33	1.39	4.93	4.39
13. Semnan	972375	10	890	1	488	469	13.79	2.30	6.79	0	6.19	6.15
14. Sistan	267600	3	620	1	527	10	12.49	1.09	6.43	0	6.27	2.3
15. Fars	1558730	21	1746	30	1432	3700	14.26	3.04	7.47	3.40	7.27	8.22
16. Qazvin	2386600	11	1999	12	136	429	14.69	2.4	7.6	2.49	4.91	6.06
17. Qom	2355751	15	1862	30	39	635	14.67	2.71	7.53	3.40	3.66	6.45
18. Kordestan	291400	9	358	1	422	212	12.58	2.2	5.88	0	6.05	5.36
19. Kerman	466200	12	840	1	399	218	13.05	2.49	6.73	0	5.99	5.38
20. Kermanshah	320860	11	588	1	264	142	12.68	2.4	6.38	0	5.58	4.96
21. Boyerahmad	231690	7	422	1	438	394	12.35	1.95	6.05	0	6.08	5.98
22. Golestan	1725900	40	402581	1	149	363	14.36	3.69	7.86	0	5	5.89
23. Gilan	222400	6	301	14	88	1266	12.31	1.79	5.71	2.64	4.48	7.14
24. Lorestan	318000	6	460	1	246	271	12.67	1.79	6.13	0	5.51	5.6
25. Mazandaran	213900	6	348	1	286	501	12.27	1.79	5.85	0	5.66	6.22
26. Markazi	476250	9	589	1	226	129	13.07	2.2	6.39	0	5.42	4.86
27. Hamedan	1723950	14	1904	1	97	587	14.36	2.64	7.55	0	4.57	6.38
28. Yazd	1008623	21	1297	100	120	221	13.82	3.04	7.17	4.61	4.79	5.4
Sum		366	35614	403	8815	11091						
Average		13.07	1271.93	14.4	315	396						

MP: Milk production, NoS: # of subunits for taking care of cows, NoC: # of cows, AIU:The amount of Internet usage, AFP: The amount of forage produced, TLU: Time spent on Learning and educational skills

The information are collected from a survey during the year 2010 by statistical organization of Iran. As we can observe, there are 753 units operating during that year with over 131637 cows producing milk. Based on the survey there were 523 active units and the others were inactive and 461 units working as industrialized complex.

The implementation of the proposed model given in Eq. (3) yields $Ln\hat{Y}_j = 16.12$ or $\hat{Y}_j = 10002329.86$. Therefore, technical efficiencies of all units are calculated in Table 2.

Table 2
Technical efficiency of all units

Province	Actual Production	Efficient production	Relative efficiency
1.East Azarbayjan	2070000	10002329.86	0.206952
2.West Azarbayjan	978910	10002329.86	0.097868
3. Ardebil	193170	10002329.86	0.019313
4. Esfahan	2521900	10002329.86	0.252131
5. Ilam	172400	10002329.86	0.017236
6. Tehran	9988420	10002329.86	0.998609
7. Bakhtiari	330500	10002329.86	0.033042
8. South Khorasan	279000	10002329.86	0.027894
9. Razavi Khorasan	5169550	10002329.86	0.516835
10. North Khorasan	399850	10002329.86	0.039976
11. Khozestan	124400	10002329.86	0.012437
12. Zanjan	137800	10002329.86	0.013777
13. Semnan	972375	10002329.86	0.097215
14. Sistan	267600	10002329.86	0.026754
15. Fars	1558730	10002329.86	0.155837
16. Qazvin	2386600	10002329.86	0.238604
17. Qom	2355751	10002329.86	0.23552
18. Kordestan	291400	10002329.86	0.029133
19. Kerman	466200	10002329.86	0.046609
20. Kermanshah	320860	10002329.86	0.032079
21. Boyerahmad	231690	10002329.86	0.023164
22. Golestan	1725900	10002329.86	0.17255
23. Gilan	222400	10002329.86	0.022235
24. Lorestan	318000	10002329.86	0.031793
25. Mazandaran	213900	10002329.86	0.021385
26. Markazi	476250	10002329.86	0.047614
27. Hamedan	1723950	10002329.86	0.172355
28. Yazd	1008623	10002329.86	0.100839
Average			0.131777
Maximum			0.998609
Minimum			0.012437

As we can observe from the results of Table 2, most of units are relatively inefficient and Tehran is the only province, which remains efficient. The other provinces were mostly operating poorly with relative efficiency of less than 20 percent. There are different reasons for having so many inefficient units such as dryness events, governmental regulation, etc. Presently, the government subsidizes milk production on one hand and the producers are allowed to increase their prices. Therefore, milk producers face with shortage of money and most of them have not been able to renovate their equipments. This hurts many businesses since they cannot easily layoff their staff, restructure their business model and cope with present conditions. The government has set a new rule to eliminate the subsidization program and deregulate the industry. This could help producers increase their prices but this deregulation could have other consequences, which could hurt this industry.

4. Conclusion

In this paper, we have presented an empirical analysis to measure the relative efficiencies of different cow husbandries. The proposed model of this paper implemented a method called deterministic frontier analysis to measure the relative efficiencies of different units. We gathered the necessary information of all units including the number of cows, the amount of internet usage, the number of subunits for taking care of cows, the amount of forage produced in each province for grazing livestock and the average hour per person training courses as independent variables and considered the amount of produced milk as dependent variable. The information was collected from all available units located in different provinces of Iran and the production function was estimated using a linear programming model. The results indicated that the capital city of Iran, Tehran, holds the highest technical efficiency, the lowest efficiency belongs to province of Ilam and other provinces mostly maintain low efficiencies. There were different reasons for having inefficient units such as government regulation, dryness year. The present study suggests that government must carefully look for alternative solutions for helping this industry.

The present study used deterministic frontier analysis to measure the relative efficiencies but we could use other popular models to measure the relative efficiency of these units such as data envelopment analysis and stochastic frontier analysis. Obviously, it would be interesting to compare the performances of all these methods and we leave it as future research for interested researchers.

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