Optimization of Energy Consumption of Broiler Production Farms using Data Envelopment Analysis Approach

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Abstract

This study applied a non-parametric method to analyze the efficiency of farmers, discriminate efficient farmers from inefficient ones and to identify wasteful uses of energy in order to optimize the energy inputs for broiler production. Data were collected from 44 broiler farms in six villages in Yazd province (Iran) by using a face-to-face questionnaire performed in January– February 2010 period. The data were collected from 44 broiler farms in six villages from Yazd province, Iran. Average capacity of surveyed farms was 18142 birds. Maximum, minimum and average meat production of farms was 2000, 3000 and 2601 kg $(1000\text{bird})^{-1}$, respectively. Total energy used in various operations during broiler production was 186885.87 MJ $(1000\text{bird})^{-1}$. We determined TE (Technical Efficiency), PTE (Pure Technical Efficiency) and SE (Scale Efficiency) of energy use in broiler farms using Data Envelopment Analysis (DEA). Two basic DEA models (CCR and BCC) were used to measure the TEs of the farmers based on five energy inputs and two outputs. The CCR and BCC models indicated 10 and 16 farmers were efficient, respectively. The average values of TE, PTE and SE of farmers were found to be 0.90, 0.93 and 0.96, respectively. The results also revealed that about 11% of the total input resources could be saved if the farmers follow the input package recommended by the DEA.

Keywords: Broiler, Data envelopment analysis, Energy savings, Management, Technical efficiency

1. Introduction

Energy, being the capacity to do work, is at the heart of all human activities, especially those concerning the production of goods and services (Canakci and Akinci, 2006). Energy is used in almost all facets of living and in all countries, and makes possible the existence of ecosystems, human civilizations and life itself. Different regions and societies adapt to their environments and determine their own energy resources and energy uses. The standards of life achieved in countries are often a function of energy related factors. On the other hand, energy can exist in many forms, and can be converted from one form to another with energy conversion technologies. We use energy carriers, produced from energy sources, in all aspects of living (Toklu et al. 2010). Nowadays hens are inter-breaded, so chicks in a short period reach to desirable weight. The intensity of energy use on broiler farms is high and studies on input-output energy pattern on broiler farms are very important. Efficient use of agricultural product energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh et al., 2002). Some researchers studied on energy consumption in broiler production by parametric methods. Jekayinfa et al. (2007) studied energy audit of poultry processing plants in southwestern Nigeria. Atilgan and Hayati (2006) analyzed cultural energy on broilers reared in different capacity poultry houses of Turkey. Results of their study showed that increasing capacity of housings decreases cultural energy input up to certain capacity and indicated that increasing housing capacity without interfering with performance could be a means for energy conservation in sustainable agriculture. Also a number of studies have been carried out on efficiency in crop and livestock farms (Latruffe et al., 2004) and other livestock production such as poultry egg (Binuomote et al., 2008; Yusef and Malomo, 2007; Ojo, 2003), dairy farm (Balcombe et al., 2006; Bravo-Ureta and Rieger, 1990), and fish farm (Inoni, 2007; Ekunwe and Emokaro, 2009).

This study presents an application of data envelopment analysis (DEA) to discriminate efficient farmers from inefficient ones. DEA is a nonparametric method in operations research and economics for the estimation of production frontiers (Charnes et al., 1994). It is used to empirically measure productive efficiency of decision making units (DMUs). DEA develops a function whose form is determined by the most efficient farmers. This method differs from the Ordinary Least Squares (OLS) statistical technique that bases comparisons relative to an average farmer. Since the work by Charnes et al. (1978), DEA can be a powerful tool when used wisely. A few of the characteristics that make it powerful are:

- DEA can handle multiple input and multiple output models.
- It doesn't require an assumption of a functional form relating inputs to outputs.
- DMUs are directly compared against a peer or combination of peers.
- Inputs and outputs can have very different units. For example, X_1 could be in units of lives saved and X_2 could be in units of dollars without requiring an a priori tradeoff between the two.

DEA has been used in energy, economic and environmental modeling in recent studies. Begum et al. (2010) calculated technical, allocative and economic efficiencies of commercial poultry farms in Bangladesh using the DEA approach under CRS and VRS specification. Zhou et al. (2008) presented a literature survey on the application of DEA to E&E studies, beginning with an introduction to the most widely used DEA techniques, which was followed by a classification of 100 publications in this field. This survey of DEA in E&E studies would be useful to researchers entering this exciting field. In the study of Chauhan et al. (2006) in the alluvial zone in the state of west Bengal in India, DEA approach was applied to determine the efficiencies of growers with regard to energy use in rice production activities. The results revealed that, on an average, about 11.6% of the total input energy could be saved if the growers follow the input package recommended by their study.

Recently, Omid et al. (2011) investigated the degree of efficiency of selected greenhouse producers in Iran and described the process of benchmarking energy inputs and output yield by applying DEA technique. Here the same methodology is adopted for selected broiler farms. The objectives were to specify energy use for broiler production, to segregate efficient farmers from inefficient ones, and to identify wasteful uses of energy inputs for broiler production in Yazd province.

2. Materials and methods

2.1 Case study and data collection

In this study, the data were collected from 44 broiler farms in six villages from Yazd province, Iran. Share of this province in broiler farms within Iran was 5% for 2009 production year, with 577 broiler farms. The production of broiler was about 1988 tons/year in Yazd province (Anonymous, 2009). Data were collected from the farmers by using a face-to-face questionnaire performed in January– February 2010 period. Farms were randomly chosen from the villages in the area of study. The sample size was determined using Neyman method and was calculated as 44 farms (Yamane , 1967).

The inputs included hours or amount of different energy sources such as chick, diesel fuel, feeds, electricity, equipment and human labor, and output energy included broiler and manure transformed to energy term by appropriate energy equivalents. Input values were converted to energy equivalents by multiplying the quantity per 1000bird.

2.2 Correlation analysis

Correlation analysis is a family of statistical tests to determine mathematically whether there are trends or relationships between two or more sets of data from the same list of items or individuals (for example, equipment and fuel consumption of farms). The tests provide a statistical yes or no as to whether a significant relationship or correlation exists between the variables (Childress, 1985).

2.3 DEA models

Data Envelopment Analysis (DEA) is becoming an increasingly popular management tool and is commonly used to evaluate the efficiency of a number of producers. A typical statistical approach is characterized as a central tendency approach and it evaluates producers relative to an average producer. In contrast, DEA is an extreme point method and compares each producer with only the "best" producers. There are two kinds of DEA models included: CCR and BCC models (Charnes et al., 1978). The CCR model is built on the assumption of constant returns to scale (CRS) of activities, but the BCC model is built on the assumption of variable returns to scale (VRS) of activities. Efficiency by DEA is defined in three different forms: overall technical efficiency (TE_{CCR}), pure technical efficiency (TE_{BCC}) and scale efficiency (SE).

2.4 Technical efficiency

Technical efficiency (TE) can be calculated by the ratio of sum of weighted outputs to sum of weighted inputs (Cooper et al., 2006):

$$\theta = \frac{\sum_{p=1}^{P} u_p y_{p,j}}{\sum_{q=1}^{Q} v_q x_{q,j}} \quad (1)$$

where ‘x’ and ‘y’ are inputs and outputs, ‘v’ and ‘u’ are input and output weights, respectively, ‘q’ is the number of inputs (q = 1,2,. . .,Q); ‘p’ is the number of outputs (p = 1,2,..,P); and ‘j’ represents j^{th} DMU.

The CCR model was initially proposed by Charnes et al. (1978). The CCR model is indicated in Eq. (2):

$$\min\ \theta \quad (2)$$

subject to:

$$\sum_{j=1}^{J} \lambda_j y_{p,j} \geq y_{p,0}$$

$$\sum_{j=1}^{J} \lambda_j x_{q,j} \leq \theta . x_{q,0}$$

$$\lambda_j \geq 0$$

where λ_j is a vector of j elements representing the influence of each farmer in determining the technical efficiency of the DMU under study, and θ is the technical efficiency (TE_{CCR}).

2.5 Pure technical efficiency

Pure technical efficiency is technical efficiency of BCC model. The BCC model was initially proposed by Banker, Charnes and Cooper (1984). The function of input-oriented BCC model for evaluating of efficiency of DMU_j (TE_{BCC}) is like CCR model, but in this model the equation $\sum_{j=1}^{J} \lambda_j = 1$ is a convexity constraint, which specifies the VRS framework (Mostafa, 2009).

Without this convexity constraint, the BCC model will be a CCR model (Eq. 2) describing a CRS situation.

2.6 Scale efficiency

Based on the CCR and BCC scores, scale efficiency defined by (Cooper et al., 2006):

$$SE = \frac{TE_{CCR}}{TE_{BCC}} \quad (3)$$

In other words decomposition of Eq. (3) can be defined by:

$$TE_{CCR} = TE_{BCC} \times SE \quad (4)$$

This decomposition, which is unique, depicts the sources of inefficiency, i.e., whether it is caused by inefficient operation (PTE) or by disadvantageous conditions displayed by the scale efficiency (SE) or by both. If the scale efficiency is less than 1, the DMU will be operating either at decreasing returns to scale (DRS) if a proportional increase of all input levels produces a less-than-proportional increase in output levels or increasing return to scale (IRS) at the converse case. This implies that resources may be transferred from DMUs operating at DRS to scale to those operating at IRS to increase average productivity at both sets of DMUs (Boussofiane et al., 1992).

By solving of CCR and BCC models, the weights of remaining inputs (diesel fuel, feed, electricity, equipment and human labor) and output (broiler and manure) would be calculated so the maximum value of θ is calculated. Because of the low contribution of chick energy in CCR and BCC models it was omitted from these models. In this study we used DEA-solver software to calculate CRS and VRS with radial distances to the efficient frontier and determine the amount of energy loss and energy savings of inefficient farmers.

3. Results and discussion

3.1 Energy inputs and correlation between energy inputs of broiler production

Average capacity of surveyed farms was 18142 birds. Minimum, maximum and average meat production of farms was 2000, 3000 and 2601 kg $(1000\text{bird})^{-1}$, respectively. Total energy used in various operations during broiler production was 186885.87 MJ $(1000\text{bird})^{-1}$.

Data in Table 2 indicates the correlation between energy inputs used in broiler production in the studied area. The value of a correlation coefficient can vary from minus one to plus one. A minus one indicates a perfect negative correlation, while a plus one indicates a perfect positive correlation. A correlation of zero means there is no relationship between the two variables. When there is a negative correlation between two variables, as the value of one variable increases, the value of the other variable decreases, and vise versa. In other words, for a negative correlation, the variables work opposite each other. When there is a positive correlation between two variables, as the value of one variable increases, the value of the other variable also increases. The variables move together. It was found, the highest value of correlation was between labor and equipment energies as 0.54, indicated as the value of labor energy or equipment energy increases, the value of the equipment energy or labor energy increases.

3.2 DEA results

In this study, we used CCR and BCC models to evaluate technical, pure technical and scale efficiencies (TE, PTE and SE, respectively) of broiler farms. The results of CCR and BCC models are shown in Table 3 and Fig 1. Based on CCR results, this study shows that only 10 farmers were relatively efficient and the remaining 34 were inefficient, i.e. their efficiency scores were below 1. But from the results of BCC model, we found 16 farmers (out of total 44 farmers) were efficient, meaning they have an efficiency score of 1 (Table 3). Other farmers who have efficiency score less than one, are inefficient in energy use. The technical, pure, scale efficiencies of the remaining 28 inefficient farmers is shown in Fig. 1. The average values of the PTE, TE and SE are summarized in Table 3. The average values (for all 44 farmers considered) of PTE, TE and SE were found to be 0.9314, 0.8954 and 0.9606, respectively. The mean value of PTE for the inefficient farmers (0.8922) indicates that there is ample scope for improving their operating practices to enhance their energy use efficiency. In a similar study, PTE, TE and SE for rice production were reported to be 0.9249, 0.7720 and 0.8302, respectively (Chauhan et al., 2006) and 0.972, 0.879 and 0.900 for greenhouse cucumber, respectively (Omid et al., 2011).

It is evident from Fig. 2 that the majority of inefficient farmers were in the SE range of 0.9–0.99. The average of SEs was low. Identifying efficient operating practices and their dissemination will help to improve efficiency not only in the case of inefficient farmers but also for some relatively efficient ones. By raising the meat yield and by decreasing energy inputs consumption the inefficient farmers can increase their energy efficiency. The efficient farmers obviously follow good operating practices. However, among the efficient farmers, some (farms: 1, 19, 34, 36-38, 40, 41, 43, 44) show better operating practices than others. Therefore, discrimination is required to be made among the efficient farmers while seeking the best operating practices. These efficient farms can be selected by inefficient DMUs as best practice DMUs, making them a composite DMU instead of using a single DMU as a benchmark. The farm1 appears nineteen times in the reference set of inefficient DMUs. This places farm1 closest to the input and output levels of most of the inefficient DMUs but uses fewer inputs. The latest column of table 3 indicated results of return to scale. The analysis shows that DMUs numbered 1, 3-7, 10, 17-19, 23, 25, 28-29, 31, 34, 36-38, 40-44 that are efficient under the CRS model are both technically and scale efficient (Table 3). The RTS indicated that all efficient farms (based on pure technical efficiency) were operating at CRS and for inefficient farms technological change is required for considerable changes in yield.

The PTE score of a farmer that is less than one indicates that, at present, he/she is using more energy than required from the different sources (Chauhan et al., 2006). Therefore, it is desired to suggest realistic levels of energy to be used from each source for every inefficient farmer in order to avert wastage of energy without reducing the yield level. Table A1 in Appendix A gives, for each inefficient farmer, the PTE, the actual energy use (MJ $(1000\text{bird})^{-1}$) and the recommended projection energy use (MJ $(1000\text{bird})^{-1}$) for each input and the percent saving in total energy use.

Table 4 summarizes the information available in Table A1. It gives the average energy spent and targeted (MJ $(1000\text{bird})^{-1}$), possible energy savings and percent contribution of each energy source in the total energy savings. We note from Table A1 that the possible overall energy saving is 11%. Fig. 3 shows the share of the various sources in the total input energy savings. It is evident from Table 4 and Fig. 3 that the maximum contribution to the total energy savings is 58% from diesel fuel, followed by feeds (26%) and electricity (16%). Electricity power was used in automatic feeding and lighting equipment's. Artificial lighting is the way to raise the production of chickens. If the housing is lit in the cooler hours before sunrise or after sunset, the chickens are able to eat more. However, day length must not be increased during the growing period of the young chicks until just before they start laying. Other energy inputs (equipment and labor) only included under 1% of energy saving. Chauhan et al. (2006) reported a total input energy of 11.6% could be saved for rice production and the maximum contribution to the total energy savings was 33% from fertilizers. In the study of Omid et al. (2011) on an average, the total input energy could be reduced by 8.5% without reducing the cucumber yield from its present. Diesel fuel carries relatively higher weights in the distribution of the virtual inputs for truly efficient producers by 76.7%.

Diesel fuel contributes 58% of the total input energy saving for inefficient farmers. The majority of the surveyed farms consumed diesel fuel to warm their rooms. In order to improve the farms environment as well as reduction of diesel fuel consumption, it is strongly suggested that the heating system efficiency is raised or replaced with alternative sources of energy such as natural gas, solar energy, etc. Feeds contributes 26% of the total input energy saving. In most cases of surveyed farms in this study, there are given free access to food and the birds are allowed to consume as much food as they wish. Broilers usually consume just enough food to meet their nutrient requirements. This control of intake is based primarily on the amount of energy in the diet.

4. Conclusions

This paper describes the application of DEA to the study for improving the energy use in the broiler production in the central region of Iran. This technique allows the determination of the best practice farms and can also provide helpful insights for farm management. DEA has helped in segregating efficient farmers from inefficient farmers. It has also helped in finding the wasteful uses of energy by inefficient farmers, ranking efficient farmers by using the CCR and BCC models and ranking energy sources by using technical, pure technical and scale efficiency. Broiler production consumed a total energy of 186885.87 MJ $(1000\text{bird})^{-1}$, which was mainly due to diesel fuel. The limited oil fuel sources implies that policy makers must determine the best regional plans for management and raisin inputs productivity in boiler production. On an average, the total input energy could be reduced by 11% without reducing the output energy from its present level by adopting the recommendations based on this study. Diesel fuel, feed and electricity had relatively higher weights in the distribution of total input energy saving for inefficient farmers.

Based on our findings, modern and well established scientific practices should be used to obtain higher technical efficiency from broiler farming like:

1) Inefficient farmers should pay more attention towards diesel, feeds and electricity sources to improve their energy productivity.

2) It is important to have a good idea of how much feeds are eaten, in particular the amount of feeds needed per kg of meat (feeds conversion).

3) There is a need for capacity training of poultry farmers and processors to enable them cope with the challenges of modern poultry farming and commercialization of the poultry sub-sector in the studied region.

4) Purchase of improved strain of one day old healthy broiler type chicks from a reputed hatchery.

Appendix A

Table A1 gives, for each inefficient farmer, the pure technical efficiency (PTE), the actual energy use, (MJ $(1000\text{bird})^{-1}$), the recommended projection energy use (MJ $(1000\text{bird})^{-1}$) for each input and the percent saving in total energy use. The complete scores for all DMUs are presented in Table 3.

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Table 1. Energy equivalents of inputs and outputs in broiler production

Inputs	Unit	Energy equivalent (MJ (1000bird)$^{-1}$)	Reference
A. Inputs			
Chick	kg	10.33	(Najafi et al., 2008)
Human labor	h	1.96	(Heidari and Omid, 2011)
Machinery			
(a) Electric motor	kg	64.8	(Chauhan et al., 2006)
(b) Steel	kg	62.7	(Chauhan et al., 2006)
(c) Polyethylene	kg	46.3	(Kittle, 1993)
Diesel fuel	l	47.8	(Kitani, 1999)
Feeds			
(a) Maize	kg	7.9	(Atilgan and Hayati 2006)
(b) Soybean meal	kg	12.06	(Atilgan and Hayati, 2006)
(c) Di calcium Phosphate	kg	10	(Alrwis and Francis, 2003)
(d) Fatty acid	kg	9	(Berg, 2002)
Minerals and vitamins	m^3	1.59	(Sainz, 2003)
Electricity	kWh	3.6	(Heidari and Omid, 2011)
B. Outputs			
Broiler	kg	10.33	(Celik, 2003)
Manure	kg	0.3	(Kizilaslan, 2009)

Table 2. Correlation between energy sources in broiler production

	Chick	Fuel	Feed	Electricity	Equipment	Labor	Output Energy
Chick	1.00						
Fuel	0.06	1.00					
Feed	0.13	0.04	1.00				
Electricity	-0.08	0.07	-0.05	1.00			
Equipment	-0.41	0.00	-0.04	0.42	1.00		
Labor	-0.17	-0.04	0.05	0.45	0.54	1.00	
Output Energy	0.15	0.32	0.34	0.11	-0.06	-0.13	1.00

Table 3. Efficiency scores of farms based on CCR and BCC models

DMU	TE_{CCR}	E_{BCC}	SE	Frequency in referent set	RTS
1	1.00	1.00	1.00	19	Constant
2	0.98	1.00	0.98	0	Increasing
3	0.85	0.88	0.97	0	Constant
4	0.85	0.87	0.98	0	Constant
5	0.86	0.88	0.97	0	Constant
6	0.89	0.90	1.00	0	Constant
7	0.97	0.97	1.00	0	Constant
8	0.88	0.89	0.99	0	Decreasing
9	0.91	0.94	0.97	0	Decreasing
10	0.75	0.85	0.88	0	Constant
11	0.98	1.00	0.98	0	Decreasing
12	0.79	0.83	0.96	0	Decreasing
13	0.75	0.91	0.82	0	Increasing
14	0.96	0.98	0.98	0	Increasing
15	0.85	0.90	0.95	0	Increasing
16	0.81	0.87	0.93	0	Increasing
17	0.92	0.94	0.99	0	Constant
18	0.79	0.85	0.93	0	Constant
19	1.00	1.00	1.00	2	Constant
20	0.92	1.00	0.92	0	Decreasing
21	0.84	0.84	1.00	0	Decreasing
22	0.95	0.95	1.00	0	Decreasing
23	0.73	0.74	0.98	0	Constant
24	0.67	0.88	0.76	0	Increasing
25	0.88	0.91	0.96	0	Constant
26	0.97	1.00	0.97	0	Decreasing
27	0.82	0.84	0.97	0	Increasing
28	0.83	0.85	0.98	0	Constant
29	0.92	0.97	0.95	0	Constant
30	0.83	0.95	0.87	0	Increasing
31	0.79	0.80	0.98	0	Constant
32	0.78	0.86	0.91	0	Decreasing
33	0.86	1.00	0.86	0	Decreasing
34	1.00	1.00	1.00	4	Constant
35	0.95	0.95	0.99	0	Decreasing
36	1.00	1.00	1.00	1	Constant
37	1.00	1.00	1.00	1	Constant
38	1.00	1.00	1.00	12	Constant
39	0.94	1.00	0.94	0	Increasing
40	1.00	1.00	1.00	1	Constant
41	1.00	1.00	1.00	2	Constant
42	0.94	0.98	0.96	0	Constant
43	1.00	1.00	1.00	1	Constant
44	1.00	1.00	1.00	1	Constant
Mean	0.90	0.93	0.96		
STD	0.09	0.07	0.05		

Table 4. Energy saving (MJ/1000bird) from different sources

Input	Present use (MJ.(1000bird)$^{-1}$)	Target use (MJ.(1000bird)$^{-1}$)	Energy saving (MJ.(1000bird)$^{-1}$)	Contribution of input to savings, %
Fuel Energy	110632.79	96073.32	14559.48	57.58
Feed	59311.40	52717.23	6594.17	26.08
Electricity	16085.73	12023.67	4062.05	16.07
Equipment	196.06	159.55	36.52	0.14
Labor	127.93	95.48	32.46	0.13
Total input energy	186885.87	161069.24	25816.63	100

Table A. The percentages in energy savings of inefficient farmers (based on BCC Mode1)

DMU	PTE	Actual Energy use MJ/1000bird					Projection Energy use MJ/1000bird					Saving %
		Fuel	Feed	Electricity	Equip	Labor	Fuel	Feed	Electricity	Equip	Labor	
3	0.88	150841.5	53868.0	15944.5	210.1	137.4	132174.8	47201.8	13971.4	184.1	120.4	12.4
4	0.87	168169.1	54063.9	16732.7	221.2	125.4	145711.2	46844.0	14498.2	191.7	108.7	13.4
5	0.88	136571.4	53098.5	11213.7	232.3	129.4	120710.7	46931.9	9911.4	205.3	114.3	11.6
6	0.90	166042.1	68043.8	10637.1	254.4	113.9	149019.5	61068.0	9546.6	228.3	102.2	10.3
7	0.97	134228.7	54155.5	10134.6	154.8	126.7	130614.4	52697.3	9861.7	150.7	123.3	2.7
8	0.89	144323.7	58552.2	13947.9	165.9	122.1	128867.6	52281.6	12454.2	148.1	109.1	10.7
9	0.94	96985.5	60894.3	15299.1	204.6	176.7	90876.8	57058.8	14335.5	191.7	165.6	6.3
10	0.85	142828.7	69749.4	20219.9	160.4	171.8	121112.3	59144.4	17145.5	136.0	145.7	15.2
12	0.83	141049.2	61815.7	16566.0	259.9	172.9	116897.9	51231.3	13729.5	215.4	143.3	17.1
13	0.91	89625.0	56112.5	14379.7	237.8	209.1	81348.6	50930.8	13051.8	215.8	189.8	9.2
14	0.98	66184.6	58011.7	13325.6	248.9	171.3	64810.0	56806.8	13048.9	243.7	167.7	2.1
15	0.90	73538.5	62155.4	15095.4	254.4	177.9	66309.7	56045.6	13611.6	229.4	160.4	9.8
16	0.87	93521.7	59723.2	11974.5	243.3	119.3	81545.0	52074.8	10441.0	212.2	104.0	12.8
17	0.94	69275.4	58552.2	28440.7	265.4	170.4	64928.8	54878.5	26656.2	248.8	159.7	6.3
18	0.85	104366.8	70569.4	9160.5	259.9	114.7	88343.3	59734.9	7754.0	220.0	97.1	15.4
21	0.84	130174.3	52811.8	17710.9	193.6	133.2	109640.1	44481.0	14917.1	163.0	112.2	15.8
22	0.95	106274.7	58552.2	23871.4	149.3	96.1	101082.5	55691.5	22705.2	142.0	91.4	4.9
23	0.74	148711.1	62247.5	24862.2	193.6	202.1	109765.7	45945.7	18351.1	142.9	149.2	26.2
24	0.88	80296.4	63875.1	10431.2	165.9	147.2	70825.8	56341.3	9200.9	146.3	129.8	11.8
25	0.91	88989.4	58452.5	13869.8	154.8	110.9	81042.3	53232.5	12631.2	141.0	101.0	8.9
27	0.84	89625.0	60601.5	22415.4	259.9	264.6	75181.4	50835.2	18803.0	218.0	222.0	16.1
28	0.85	129891.3	58552.2	22924.2	165.9	179.0	110352.7	49744.6	19475.8	140.9	152.0	15.0
29	0.97	76790.6	57692.6	21258.9	160.4	92.4	74449.0	55933.3	20610.7	155.5	89.5	3.0
30	0.95	74223.6	58552.2	11033.0	165.9	147.3	70744.7	55807.8	10515.9	158.1	140.4	4.7
31	0.80	119004.1	55879.7	28078.5	271.0	198.4	95775.5	44972.4	22597.8	218.1	159.7	19.5
32	0.86	106537.9	75239.1	29360.2	276.5	172.4	91437.9	64575.2	25198.8	237.3	148.0	14.2
35	0.95	93177.4	59508.9	15512.5	149.3	127.2	88972.7	56823.6	14812.5	142.6	121.4	4.5
42	0.98	94770.8	53734.5	9861.1	143.8	97.1	92808.4	52621.9	9656.9	140.8	95.1	2.1

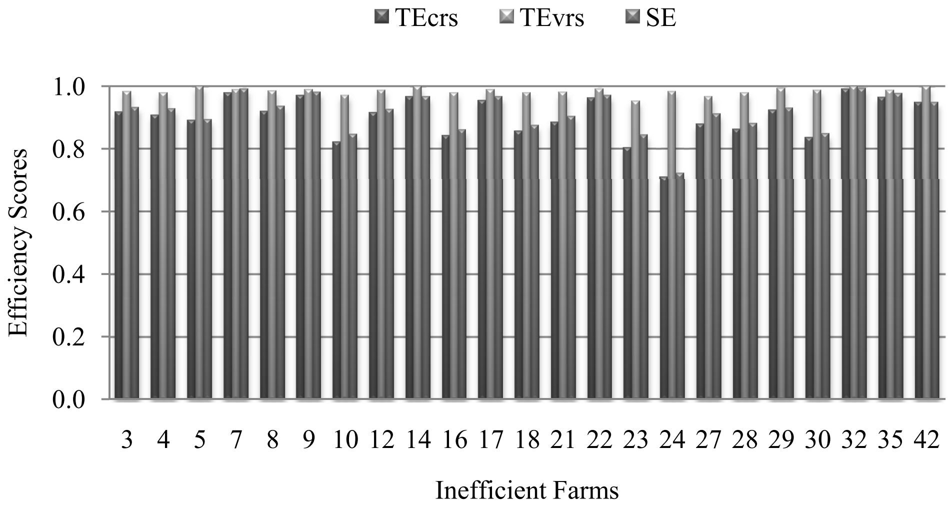

Figure 1. The overall, pure and scale efficiencies of inefficient farms

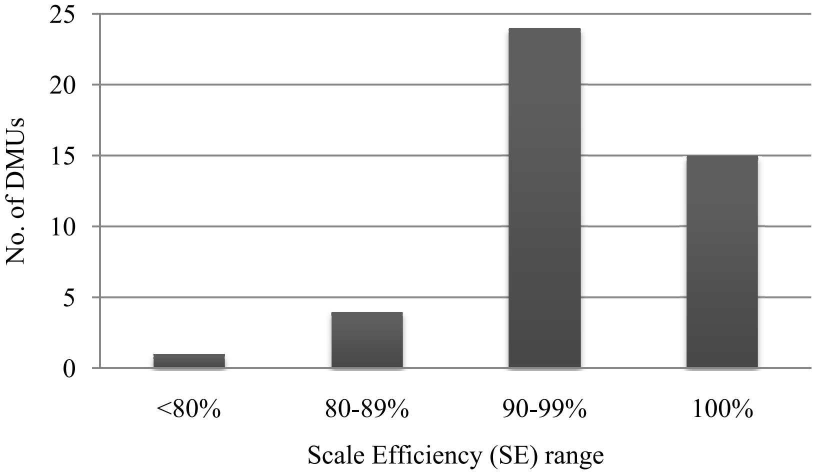

Figure 2. Scale efficiency distribution of farms

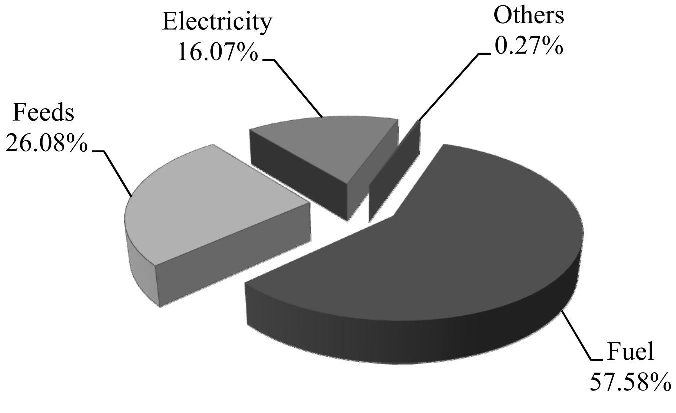

Figure 3. Total potential improvement summary