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Eco-Efficiency Valuation of the Iranian Power Plants by Data Envelopment Analisis: Dea Approach

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ABSTRACT

The aim of economic firms; based on the economic principle; is to get the maximum amount of outputs from the minimum amount of inputs. Such principle is related to the demand for higher efficiency in the firms.On the other hand, nowadays, environmental considerations for the purpose of initiation and development of activities of various industries is a serious and inevitable factor, since statistics clearly indicate that the main factor in destroying and polluting environment among human factors is conversion and consumption of various types of energy. And we know that energy consumption will not remain fixed since its increase is foreseen.

Power plants, as the main producers of power in Iran, utilize different sources such as fuel, human resources, and fiscal ones. The present study seeks to measure the eco-efficiency and technical efficiency of power plants in Iran, and to determine the relation between fuel type and eco-efficiency by means of data envelopment analysis (DEA) method.

In this study, 40 power plants of Iran functioning between 2003 and 2007 have been underlined. Based on the results gathered through (DEA) method, and by utilizing Windeap software, the average eco-efficiency of these power plants was measured such results indicate that the eco-efficiency of power plants of Iran within the specified period has declined.

Q 56: JEL classification
KEY WORDS: Eco-efficiency– Power plants – data envelopment analysis (DEA)

INTRODUCTION

One of the most important factors for production in every country is various sources of energy and from this view point access to these energies is one of the developmental and progressive factors in countries. From the natural available energies it can be pointed out to available energies it can be pointed out to fossilize fuel energy, running waters, wind and solar energy that in present time using of fossilize fuels is most convenient and easily obtainable for mankind, and the man from this energy is being plentifully benefited for supplying own needs in living and working place. Continuous increasing of population, efforts of countries for access to higher local gross production, development of industries by using energy and etc, have been confronted countries in the world with deficit of energy inclouding of power energy, and in the other hand increasing the consumption of energy because of increasing the environmental pollutants the rests the human life.

By considering that most of available fossilize energy sources in the earth are decreasing and in some cases are towards the annihilation and also using of this kind of energy carrier (trans porter) severely threats the environment of mankind and on the other hand using of different energies and also power energy are necessary for living in the industrial and modern era. Promotion and improvement of environ mental efficiency in the energy transporters, increasing of utilization and output, using of fossilize fuels and reliance to new energies is inevitable necessity.

Internal Studies

1- Leili Niakan in her MS thesis with title of “measuring technical efficiency of country's thermal power plants by stochastic frontier Analysis (SFA) method and comparison with selected developing countries” by the aid of stochastic frontier analysis (SFA) and comparison, technical efficiency of thermal power plant evaluated in 22 developing countries. In this thesis 40 power thermal plants in Iran have been evaluated between 2003- 2006years. The results indicate that average of technical efficiency in these power plants is equal to 93 percent increasing the installed capacity of power plant and changing the consumed fuel from gasoil and fuel oil to natural Gas significantly increases the technical efficiency of power plants. Average of 22 selected developing countries between 2003-2006 years is 91/7 percent. Between the present countries in sample, Egypt, Malaysia and South Africa have the most technical efficiency and Armenia and Qatar have the least technical efficiency.

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Average of technical efficiency of Iran's thermal power plants in this period is more than estimated average of sample. (Niakan- 2009)

2- Maisam Nasiri tajabadi in his MS thesis under the title of Bio efficiency case study of urban transportation system in Tehran reviews the Bio efficiency of urban transportation. In this thesis suitable giving's and receiving's (inputs and outputs) have been used for assessment of urban transportation, for this aim has been used of Data envelopment analysis and obtained result from this study shows that Bio efficiency of urban train transportation (metro) is higher in relation to other systems.

International studies

1- Savolainen in a study with title of relative efficiency of transportation systems in Europe has been done a comparison between companies of offering transportation services in throughout the European continent.

In this study has been reviewed on rail, aviation and marine transportation systems based on this study among the companies of offering aviation services, there is not more difference between most efficient and most in efficient companies. In system of transportation by rail, it is observed a great difference in technical efficiency among the different countries and also between different years for a company. Procedure in this investigation was Data envelopment Analysis (DEA).

2- Pekka J.horhonen and Mikulas Luptacik in the year of 2003 in an article by title of bio efficiency analysis of power plants and expansion of Data envelopment analysis by using of two methods it can be introduce a tool for measuring of bio efficiency. This device has been used for measuring of efficiency in 24 thermal power plants in one of the European countries. First method has been formed of two section, in first section technical efficiency is measured and in second section, it is done the environmental efficiency and finally combination of these two indexes would be a measure (criterion) for measuring the bio efficiency, in second method we increase favorable outputs (receiving) and decrease the unfavorable inputs and outputs (pollutions) and efficiency which obtains by this way can be a measure (criterion) for measuring of bio efficiency. Comparison of two methods would be leading to equal results. However second method provides deeper section in relation to bio efficiency (Horhonen, Luptacik-2003)

Eco-efficiency measurement framework

How exactly to determine the numerator and denominator of The "eco-efficiency equation", is currently subject to international research and development (Seppälä et al., 2005).

Although, the equation is open to widely differing interpretations depending on which viewpoint is selected, it has become customary to define eco-efficiency as a combination of economic and environmental (ecological) values, expressed by the ratio of economic value/environmental impact or,environmental impact/economic value (Keffer and Shimp,1999; Sturm et al., 2002).

There are still no standard indicators and measurement for economic and environmental values, as well as eco-efficiency(Reijnders, 1998). United Nations Conference on Trade and Development (UNCTAD). suggests using value added indicators to represent performance indicators, such as Sales Revenue (UNCTD, 2003). At regional level, Seppälä et al. (2005) apply three economic indicators to represent the value of products and services I the Kymenlaakso region, that is, gross domestic product (GDP),value added of industries and output at basic prices.

In the process of arriving at eco-efficiency ratios, cost orvalues should be aggregated into one score. Huppes andIshikawa (2005) conclude two main domains types of valueand cost aggregation, cost-benefit analysis (CBA) and life cyclecosting (LCC), both developed in the middle of the 20th century.

Envelopment analysis method (DEA)

The above method is a mathematical programming method that is used for assessment of operation in decision maker units (DMU). This method by using of available in formations of inputs and out puts estimates the amount of efficiency for each one of the agencies and the units are not compared with a pre determined level of standard (or a distinct function) but criterions is decision maker units that in the same conditions are doing same activities in 1997 in the united states and Europe simultaneously would be possible practical measuring of efficiency according to Farel's definition (1957) and with randomize border (marginal) analysis method.

In data envelopment analysis method by considering of technology based on variable output in relation to scale it may be obtained efficiency of scale for each of agencies and this needs using of two methods of CRS (Constant output in relation to scale) and VRS (variable output in relation to scale) in DEA model (data envelopment analysis) the criterion for technical efficiency in CRS case is analysis (divided) to scales efficiency and mere (pure) technical efficiency (manage mental efficiency) if amount of technical efficiency for a special agency in cases of CRS and VRS would be different, this shows being of scale's efficiency.

Data envelopment analysis with assumption of constant output in relation to scale (CCR)

Charnez, Cooper and Rodez in 1978 Presented data comprehensive analysis method by assumption of constant output in relation to scale (CCR) if would be in formations about m producing agent (factor) and S product for each of N agencies, calculation will be as following:

$$\max z = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

$$\text{Subject to}: \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$$u_r, v \geq 0$$

i, j = 1,2,…,n

In above equation Y is representative of model's outputs and S indicates the numbers of model's outputs, X indicates inputs and M is numbers of inputs, U and V are weight of variable in weighting average in this relation the aim (purpose) is obtaining the optimum amounts of U and V.

So that the ratio of weighted sum of products to weighted sum of producing factors maximize with amount (level) of efficiency of each agency.

The problem of above relation is that it has in finite optimum answers, for avoiding of this problem it can be added limitation of $\sum x_{ij0} v_i = 1$ to model and convert it to linear programming form. After adding this limitation, we will have:

$$\max z = \sum y_{rj0} u_r \qquad r = 1,\ldots., s$$

$$st: \sum y_{ri} u_r - \sum x_{ij} v_i \leq 0 \qquad r = 1,\ldots, s \qquad i = 1,\ldots, n$$

$$\sum x_{ij0} v_i = 1 \qquad i = 1,\ldots, n$$

$$u_r, v_i \geq 0$$

So that, this linear programming model is different from previous case. This form is known to increasing form in DEA programming problem. Because linear programming method for solving the Dogan's problem means that it needs to fewer limitations in relation to producing method. Using the Dogan's form of this problem (by orientation of input) is suitable.

$$\min y_0 = \theta$$

$$st: \sum \lambda_i y_{ri} \geq y_{r0} \qquad j = 1,\ldots., n$$

$$\theta x_{i0} - \sum \lambda_j x_{ij} \geq 0 \qquad j = 1,\ldots., n$$

$$\theta, \lambda_j \geq 0$$

In fact θ shows input of optimum ratio required for acquisition of distinct amount of product by used level of it. Numerical amount of θ is between 0 and 1 and so far to be closer to one (1) demonstrates higher level of efficiency index I also indicates the input orientation in solving the Dogan's problem.

The first limitation in above relation shows that whether actual amounts of produced output by Ith agency by used input can be more than this? The second limitation states that produced input that is applied by Ith agency at least must be applied equal to producing input by reference agency. In fact above model is seeking a linear combination from all of the agencies.

This combination while produces minimum output equal to Ith unit, consumes only a fraction of inputs of Ith decision maker unit this fraction is the very θ variable that is minimized (Emami Meibodi-2000). By solving this model for the entire N available agencies, the efficiency level of them will be estimated. θ means that agency has been placed on equal (same) production curve.

Or on the marginal production function and according to Farel's definition has hundred percent relative efficiency.Dogan's form with output orientation is as following:

$$TE_{0j}^{crs}: \max_i, \theta\theta_i \qquad j = 1,\ldots, N$$

$$st: \Sigma Y_h \lambda_j \qquad j = 1,\ldots., n$$

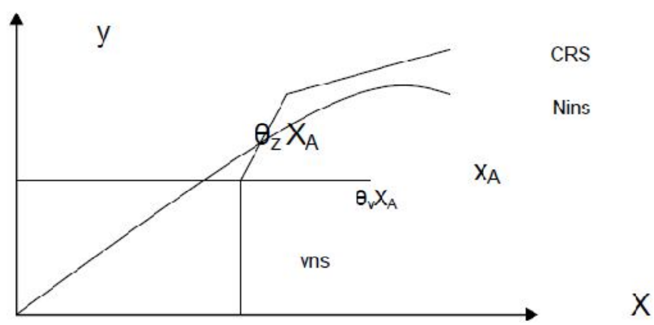
$$\lambda_i \geq 0$$

$$\sum \lambda j \geq 0 \qquad j = 1,...., n$$

Data envelopment analysis method with variable output in relation to scale

The assumption of constant output relation to scale is considered whenever the agencies act in optimum scale (min LAC), but in most of cases agency due to computational effects, limitations and so on does not act in optimum scale. And encounters with disorder, using of variable output assumption provides possibility of separation (dividing) of technical efficiency to two part of scale's efficiency and manage mental efficiency. In order to enforcement of variable output assumption in relation to scale in linear programming Dogan's problem, limitation of $\sum_{j=1}^{n} \lambda_j = 1$ is added to CCR model. The new model states only this fact that the agency doesn't act in constant output range in relation to scale, and for determining the type of output in relation to scale it is necessary to change the third limitation, for example in descending output relation to scale the, limitation changes as $\sum_{j=1}^{n} \lambda_j \leq 1$ the nature of output in relation to scale in a special agency is determined by comparing the technical efficiency in case of non ascending output in relation to amount of variable technical efficiency relative to scale.If both of them to be equal then the considered agency confronts with descending output in relation to scale.

Unless the condition of ascending output in relation to scale to be established but as was said in case of variable output in relation to scale, technical efficiency is divide able (separately) to scale's efficiency and management efficiency. (Quelli 1998)



Unfavorable outputs

In line with attention to environment issues unfavorable outputs of productions and social declivities such as air pollution and solid and aqueous wastes increasingly are disagreeable. Hence developing the technologies with less unfavorable outputs is an important issue in all aspects of production. In DEA model usually producing more output in relation to less input is efficiency but in case of being unfavorable output, technologies with more favorable output and less unfavorable output on relation to less input sources must be considered as efficiency.

Assume that units of decision maker each one has 3 factor, favorable inputs and outputs and unfavorable outputs which are stated $x \in R^m$ ، $y^g \in R^{s1}$ ، $y^b \in R^{s2}$ respectively. We have the matrices of X, Y^g, Y^b as:

$$X = [x_1, ..., x_n] \in R^{m \times n}$$
$$Y^g = [y_1^g, ... y_n^g] \in R^{s1 \times n}$$
$$Y^b = [y_1^b, ... y_n^b] \in R^{s2 \times n}$$
$$X > 0, Y^b > 0, Y^g > 0$$

Sum of the possible production function is stated as below:

$$P = \{(x, y^g, y^b) \mid x \geq X\lambda, y^g \leq Y^g\lambda, y^b \geq Y^b\lambda, \lambda \geq 0\}$$

Where $\lambda \in R^n$ is vector of density. Is should be noticed that above definition is related to constant output in relation to scale.[1]

[1] Cooper, William- Seiford, Lawrence- Tone, Kworu- Data Envelopment Analysis- second edition- Springer 2007

Related with stated definition the above model can be modified as following:

$$\rho^* = \min \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}}}{1 + \frac{1}{s_1 + s_2}\left(\sum_{r=1}^{s_1}\frac{s_r^g}{y_{ro}^g} + \sum_{r=1}^{s_1}\frac{s_r^b}{y_{ro}^b}\right)}$$

$$x_o = X\lambda + s^-$$

$$y_o^g = Y^g\lambda - s^g$$

$$y_o^b = Y^b\lambda - s^b$$

$$s^- \geq 0, s^g \geq 0, s^b \geq 0, \lambda \geq 0$$

Vectors of S and S^b are related to surplus of unfavorable input S and out puts where S^g in diskettes deficit of favorable outputs the above target (Considered) function is strictly descending by attention to si (for each I) and S^g_r (for each r) and S_r^b (for each r)and amount of target satisfy's in the condition of $0< P^0 \leq 1$ if would be the answer of above equation (s^- , s^g, s^b, λ^0) ,then we will have that the above model in case of being unfavorable outputs is efficient if and only if which is equal to 0= s^-, s^g, s^b and if would not be efficient then $p^0<1$ can be proved that if would be deleted surplus of unfavorable input and output and also to be removed deficit of favorable outputs it will be efficient. [2]

ANALYSIS OF THE RESULTS

In this section has been paid to measuring of bio efficiency of Iran's thermal power plants that is by using of windup software and by using of data envelopment analysis have been estimated in the form of output basis (based on output)

Variable of model:

collected in formations includes of three input (institute) of man power, capital and consumed fuel that are applied in thermal power plants for generation of electricity (power) the fuel includes of Gas oil, furnace oil and natural Gas these fuels are used regarding to their thermal content in terms of million B tu (trazve) in the phase of power generating man power in terms of the numbers of occupied personnel in power plants is measured.

Installed production capacity of power plant is in terms of megawatt (MW)

Power plants	2003	2004	2005	2006	2007
Tarasht	1	1	1	1	1
Besat	0.834	0.909	0.923	1	0.8607
Isfahan	1	0.969	0.941	0.82	0.901
Ghaem	0.709	0.931	0.951	0.919	0.852
Loshan	0.734	0.802	0.889	0.724	0.8
Zarand	1	1	1	1	1
Mashahd	0.716	0.706	0.752	0.566	1
Neka	0.982	1	1	1	0.994
Varamin	0.945	0.987	0.9	0.906	1
Bandar	1	0.82	0.819	0.978	0.869
Montazeri	1	1	1	1	1
Tose	0.677	0.934	0.965	0.726	0.861
Tabriz	0.891	0.892	0.978	0.746	0.738
Rajaii	0.928	1	1	1	0.994
Biston	0.841	0.986	0.976	0.794	0.899
Mofateh	0.73	0.845	0.845	0.763	0.837
Iranshahr	1	1	1	0.796	1
Shazand	1	1	1	0.335	1
Shiraz	0.847	0.823	0.861	0.541	0.606
Boshehr	0.982	0.976	0.983	0.862	0.456
Drood	1	1	1	1	1
Zanbagh	0.989	0.946	0.889	0.572	0.452
Rey	0.585	0.625	0.604	0.525	0.498
Kenarak	0.984	0.96	0.987	0.64	0.62

[2] Cooper, William- Seiford, Lawrence- Tone, Kworu- Data Envelopment Analysis- second edition- Springer 2007

Thermal Power Plants Performance 2003-2007

Power plants	2003	2004	2005	2006	2007
Uromieh	1	1	1	0.993	1
Shiravan	0.926	0.926	0.913	0.579	0.523
Shariati	0.767	0.894	0.884	0.767	0.437
Sofian	0.968	0.967	0.968	0.91	0.657
Zahedan	0.861	0.914	0.893	0.692	1
Ghaen	0.993	0.997	0.991	1	0.733
Hesa	0.996	1	1	1	0.946
Kazeron	0.861	1	1	0.724	1
Kangan	0.938	0.997	0.937	0.856	1
Kerman	1	1	1	0.716	0.802
Abadan	0.873	0.94	0.897	0.984	0.83
Gilan	1	1	1	1	1
Qom	0.759	1	1	0.964	1
Neishabor	0.833	1	0.932	1	0.956
Fars	0.883	1	1	1	1
Khoy	0.852	0.991	0.976	0.974	0.977
average	0.897	0.943	0.941	0.834	0.851

Thermal Power Plants Performance 2003-2007

The table shows that power plants' average of bio efficiency have reduced in the years.

Power plants	2003	2004	2005	2006	2007
Tarasht	0.398	0.638	0.655	0.455	0.576
Besat	1	0.802	0.7	0.629	0.739
Isfahan	0.659	0.938	0.897	0.812	1
Ghaem	1	1	1	0.77	0.876
Loshan	0.114	0.91	0.931	0.886	1
Zarand	0.288	0.922	1	0.384	1
Mashahd	0.985	0.49	0.445	0.602	0.983
Neka	1	0.47	0.478	0.577	0.314
Varamin	0.587	0.614	0.603	0.986	0.392
Bandar	0.642	1	1	1	0.819
Montazeri	0.689	1	1	1	0.976
Tose	0.502	0.995	0.983	0.874	0.779
Tabriz	0.989	1	1	0.995	0.953
Rajaii	0.97	1	1	0.98	1
Biston	0.926	1	0.979	0.494	1
Mofateh	0.971	0.733	0.981	0.937	0.925
Iranshahr	0.624	0.936	0.939	0.895	0.985
Shazand	0.982	0.989	0.985	0.947	0.957
Shiraz	0.84	0.976	0.949	0.991	0.996
Boshehr	0.99	0.993	0.991	0.996	0.438
Drood	2003	2004	2005	1385	1386
Zanbagh	0.398	0.638	0.655	0.455	0.576
Rey	1	0.802	0.7	0.629	0.739
Kenarak	0.659	0.938	0.897	0.812	1

Iran Power Plants Performance in view of scale efficiency

The table shows that thermal power plants Performance in view of scale efficiency have increased in the years.

Power plants	2003	2004	2005	2006	2007
Tarasht	2.513	1.567	1.527	2.198	1.736
Zarand	1.000	1.247	1.429	1.590	1.353
Mashahd	1.517	1.066	1.115	1.232	1.000
Varamin	1.000	1.000	1.000	1.299	1.142
Montazeri	8.772	1.099	1.074	1.129	1.000
Iranshahr	3.472	1.085	1.000	2.604	1.000
Shazand	1.015	2.041	2.247	1.661	1.017
Dorod	1.000	2.128	2.092	1.733	3.185
Uromieh	1.673	1.629	1.658	1.014	2.551
Zahedan	1.472	1.000	1.000	1.000	1.221
Kazeron	1.347	1.000	1.000	1.000	1.025
Kangan	1.831	1.005	1.017	1.114	1.284
Gilan	0.927	1.000	1.000	0.968	1.049
Qom	0.910	1.000	1.000	0.959	1.000
Fars	0.914	1.000	0.997	1.874	1.000
Neka	0.858	1.353	0.984	0.979	1.075
Rajaii	1.202	1.054	1.028	1.012	1.009
Khoy	0.748	0.998	0.975	0.868	1.021

Iran Power Plants performance in view of management efficiency2003-2007

Power plants	2003	2004	2005	2006	2007
Neishabor	0.793	1.006	1.002	0.801	0.960
Hasa	0.653	0.976	0.950	0.783	2.103
Isfahan	0.671	1.469	0.929	0.764	0.902
Biston	0.607	0.946	0.983	0.749	0.904
Bandar	0.622	0.945	1.380	0.760	0.905
Tose	0.581	0.949	0.975	0.734	0.862
Ghaem	0.541	0.999	0.924	0.719	0.860
Mofateh	0.550	0.867	0.941	0.973	0.845
Abadan	0.533	0.879	0.827	0.971	0.910
Besat	0.542	0.844	0.824	0.721	0.807
Kerman	0.620	0.827	0.826	0.703	0.887
Lushan	0.520	0.811	0.776	0.702	0.801
Tabriz	0.518	0.778	0.790	1.033	0.795
Ghaen	0.469	0.951	0.794	0.684	1.198
Sofian	1.254	0.828	0.709	0.626	0.916
Kenarak	0.449	0.679	0.825	0.609	0.745
Shiraz	0.655	0.718	0.893	0.554	0.690
Rey	1.093	0.750	0.735	0.514	0.547
Shariati	0.823	0.668	0.534	0.540	0.508
Boshehr	0.414	0.535	0.564	0.518	0.708
Zanbagh	0.289	0.610	0.571	0.522	0.481
Shiravan	0.313	0.544	0.119	0.103	0.477
Avrage	1.142	1.021	1.110	0.983	1.062

Iran Power Plants performance in view of management efficiency 2003-2007

The table shows that thermal power plants' average of management efficiency has reduced in the years.

Conclusion

In this article it has been paid to measuring and calculation the amounts of bio efficiency in 40 thermal power plants of country. By this aim it has been used the statistics related to power energy production processes and factor and inputs required for this for mentioned agencies in a five year them that is from 2003 until 2007 .

Totally fin ding and results of this study are as following:

1- The results of applying DEA method in dictate that average bio efficiency of 40 thermal power plants in country between the years of 2003 until 2007 has been revved from% 0.89 to % 0.85

2- Results of applying DEA method show that average of scale efficiency in 40 thermal power plant of country between the years of 2003 until 1386 has been increased from % 0.78 to % 0.859

3- Results by applying DEA show that average of manage mental efficiency in 40 thermal power plant of country between the years of 2003 until 2007 has been reduced from 1.142 to 1.06

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