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Measuring environmental performance in Iran by using Malmquist index

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ABSTRACT: Healthy environment is an inseparable component of any nation development. Therefore, it is a requirement of economic development to plan for its quality improvement. The main aim of present study is to investigate the performance of Iranian environment by using numeric indices. To this end, two groups of outputs should be defined: good outputs and bad outputs. Then, an index is defined for each output. We use distance functions to define an index for each output. Distance functions only need information on input and product. Since bad products have no market, they lack any market price. To the same reason, environmental index performance is computed by distance functions and Malmquist's numeric index. In fact, the aim is to find an index on the ratio of good output to bad one. The study was conducted between 1994 through 2007. The findings indicate that Iran has no good performance within this period and the best environmental performance is seen in 1995 and the worst one in 1994.

***Keywords*:** data envelopment analysis, distance functions, environmental performance index.

INTRODUCTION

Healthy environment is an inseparable component of any nation development. Therefore, it is a requirement of economic development to plan for its quality improvement. Respecting the environment and its importance is human life is an issue one cannot neglect it easily. The importance of planning in this area is very high in any nation. As a developing country, Iran attempts to prevent pollution and to improve environment quality by entering into environmental discussion. As the second biggest owner of natural gas and the third biggest owner of oil resources in the world, Iran is today facing with air pollution due to increasingly consumption of fossil fuels as well as old manufacturing and service providing technologies. Air pollution is a current radical environmental discussion. So, in present research, Carbon Dioxide is mentioned as the most important air polluter and we have used it to investigate the index. Although more production results into more pollution, the rate of pollution can be in optimal levels in terms of utilized inputs. However, the statistics shows weak performance of Iran in this field. Global environmental performance index shows that by acquiring score 60 in 2010, Iran ranked 78 among 163 countries which show 11 ranks down compared to 2008. Used index in present paper helps to study Iranian environmental performance within 14 years. This index shows Iranian environmental performance in macro level. It is constructed by distance functions. Distance functions only need inputs and outputs of production since bad outputs have no official and strong market. Since, they have no observable price, we use distance functions. Likewise, distance functions have a relatively simple structure. They have close relations top production border concepts. The main thinking beyond such functions is too simple. The concept of distance function was coined by Malmquist, (1953) and Shepherd (1953). Distance functions make it possible to explain multi-input and multiproduct production technology without any need to determine behavioral aims (i.e. minimizing the costs or maximizing the profits). In distance function discussion, one can define both products – oriented and input – oriented distance functions. Input – oriented distance function emphasized on this trait of the technology which mitigates input verdict to the minimum possible level by assuming a fixed product. Product – oriented distance function respects to increase the products to the maximum possible level by assuming input verdict stability.

Research background

In 1996, Taitka studied environmental performance indices. He computed one index which was simultaneously produced for good (desired) outputs and polluters or bad (undesired) outputs. Taitka recommends Data Envelopment Analysis (DEA) to evaluate environmental performance. Farr et al, (2000) used an official numeric index to study environmental performance. Their index is computed by using DEA. This index measures the degree by which a company (factory or industry or country) has been successful to manufacture good products while a tangible mitigation is happened in manufacturing bad products. They used this technique to measure environmental performance of OECD members in 1990. Among studied countries, France had the best environmental performance (score 2.3). By using DEA, Hains, (1993) devised a model to prevent pollution. He used chemicals and chemical residues as the input and output in chemical industries. Then, he studied the environmental efficiency of these industries. The result was the environmental improvement along with technological advancements in studied industries. Jean Françoise et al, (2006) studied environmental performance indices. In their empirical study in Canada, they investigated EPI indices in products of Canadian corporations.

By assuming discount return to scale and unfixed return to scale as well as DEA, Zhou et al, (2006) studied environmental performance index. They also utilized non-linear planning model and assessed carbon emission in eight regions. Yin et al, (2010) studied environmental efficiency and resources in Chinese provinces. They acquired a comprehensive measurement on environmental efficiency and resources of these provinces by using DEA and different models. Then, they discussed on improvements in environmental and energy efficiency. In Iran, DEA is used in different cases including agricultural productivity assessment and/or rice cultivation performance appraisal and studying the efficacy of companies in stock exchange.

MATERIALS AND METHODS

Metodology

Here, we initially study DEA technique in brief and then we address research methodology.

Data Envelopment Analysis Technique

Over fifty years ago, DEA was coined by Farrel. He never thought that in less than half a century, his discussion progressed in a manner that it rises as an efficient technique to analyze the performance of decision making units in most sciences from mathematics to technical, engineering, economy and other disciples. Since the beginning of discussions on DEA in 1978 by Charnes, Cooper and Rodhes, various studies are conducted in this regard. One should name Professor Beasely and Professor Sifford as the global pioneers of efficiency evaluation (Emami Meybodi, 2000).

DEA is used to evaluate the efficiency of Decision Making Units (DMU). Its initial formulation is:

$$\text{Efficiency}=\frac{\text{outputs}}{\text{inputs}} \quad (1)$$

This formulation is used to study the efficiency of homogeneous units. In 1962, Farrel suggested to add weight ratios to inputs and outputs to compute the efficiency of heterogeneous units as below:

$$\frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}\text{Efficiency}= \quad (2)$$

DEA is a technique to evaluate the efficiency of organizational units called as decision making units. These are units where homogenous inputs are used to reach homogenous outputs. As said, DEA was coined by Charnes, Cooper and Rodhes in 1978. They provided below model to measure the efficiency of j_o unit compared to a set of units (Charnes et al, 1994: 5 – 33):

$$Max\ h_0=\frac{\sum_r u_r y_{rj_0}}{\sum_r v_i x_{ij_0}} \quad (3)$$

Subject to

$$\frac{\sum_r u_r y_{rj_0}}{\sum_r v_i x_{ij_0}} \leq 1\ for\ each\ unit\ j. \quad (4)$$

y_{rj} = r*th* output from j*th* unit
X_{ij} = i*th* output from j*th* unit
u_r = dedicated weight to r output

v_i = dedicated weight to i output
n = the quantity of data
S = the quantity of outputs
m = the quantity of inputs
ε = negative rate an Arachmidosian small measure

Here, if $h_o = 1$, we say that j_o unit is efficient compare to other units while if it is smaller than 1, it's efficiency is lower that other units. This is nonlinear model which should be converted into a linear one in order to be resolved. According to above model, if a decision making unit can achieve more outcome with lower consumed resources compared to other units, it is called as an efficient unit. Then, other units are categorized based on achieved results.

Extracting environmental performance index

In this section, we expand performance index. One trait of this index is that it is constructed by distance functions. Distance functions are complete and comprehensive functions which shape a natural and simple infrastructure to devise a numeric index. In present study, such trait is used to build a numeric index for good indices and one numeric index for bad outputs. Finally, environmental performance index is achieved through two distance functions.

We assume that input vector is indicated by $x=(x_1,\ldots\ldots x_N)$ vector and desired outputs by $y=(y_1\ldots\ldots y_M)$ vector and undesired outputs by $b=(b_1\ldots\ldots b_j)$ vector. Technology includes all possible vectors (x, y, b).

$$T=\{(x,y,b): x \text{ can produce } (y,b)\} \quad (5)$$

To confirm defined technology that produces both good and bad outputs, we introduce below two traits:

If $(x,y,b) \in T$ and $0 \le \theta \le 1$ then $(x,\theta y,\theta b) \in T$ If $(x,y,b) \in T$ and $b=0$ then $y=0$	(6)

The first trait shows weak access to outputs. It indicates that proportionate mitigation of good and bad outputs is possible. The second trait shows that in technological and economic terms, simultaneous production of good products without bad ones is impossible. In fact, it means that the only way to eliminate bad products is to stop good ones. Overall, these two variables are null joint.

In addition to above traits, T is a package in which good inputs and products are freely accessible (Farr and Primont, 1995).

Now that the production function is determined by a set of technologies, we define a representative function by which one can compute the numeric indices. Here, we use direct technique and production function generalizations since it allows us to study both mentioned traits. They are called distance functions which play an interesting role in numeric theory background.

By Shepherd definition (1970), we can write the extracted distance function as below:

$$D_y(x,y,b) = \inf\{x : (\Theta, \tfrac{y}{\theta}, b) \in T\} \quad (7)$$

Where, INFIMUM is a point explained as the relative maximum potential outputs by inputs and bad output as well as technology.

It is the representative of technology function, overall function and performance. This function is +1 for homogenous good products. According to minor economy theory, the attributes of this function are similar to T technology function. Such distance function is the platform of our preliminary numeric index which is nominally an index of good products. We assume that b^0 and x^0 are vectors of inputs and bad products respectively. Likewise, we assume that y^1 and y^k are two observations from good product vector. To compare these variables, we need to compute numeric indices. According to current standards in the literature, K, 1, 0 numeric indices can show the observations of an assumed company (in different time lags) or they can refer to different companies (industries or countries) in a given time.

According to general idea introduced by Malquist, numeric index for good product is computed as below:

$$Q_y(x^0,b^0,y^k,y^l) = \frac{Dy(x0,yk,b0)}{Dy(x0,yl,b0)} \quad (8)$$

In fact, above index shows the relative success in expanding good products while inputs and bad products are fixed. This index satisfies below indices (Fisher's Test, 1922):

$$\begin{aligned}
&\text{Monotonicity: } Q_y(x^0,b^0,\lambda y^k,y^l) = \lambda Q_y(x^0,b^0,y^k,y^l)\\
&\text{Time involution: } Q_y(x^0,b^0,y^k,y^l)Q_y(x^0,b^0,y^l,y^k) = 1\\
&\text{Translation: } Q_y(x^0,b^0,y^k,y^l)Q_y(x^0,b^0,y^l,y^s) = Q_y(x^0,b^0,y^k,y^s)\\
&\text{Dimension: } Q_y(x^0,b^0,\lambda y^k,\lambda y^l) = Q_y(x^0,b^0,y^k,y^l)
\end{aligned} \quad (9)$$

Below: we address to the extraction of one numeric index for bad output. At first, we start by a distance function which mitigates the rising ratio in bad outputs. It means that we define below function by input – oriented type input function (Grosskopf et al, 2004):

$$D_b(x, y, b) = \sup\{\lambda : (x, y, \frac{b}{\lambda}) \in T\} \quad (10)$$

It is a+1 homogenous function for bad outputs. Likewise, its attributes are identical to T function. We assume that x^0 and y^0 are given and fixed amounts for inputs and bad products. In the meantime, b^1 and b^k are two vectors for bad products that we need to compare our indices. The numeric index for bad products is defined as below:

$$Q_b(x^0, y^0, b^k, b^l) = \frac{Db\ (x0,y0,bk)}{Db\ (x0,y0,bl)} \quad (11)$$

This index shows relative success in reducing bad products while we have kept inputs and good products fixed. Four Fisher's tests on bad output indices mentioned on a certain bad product are also true here.
Finally, we define environmental performance index by Hicks-Morsteen productivity index as below:

$$E^{k,l}(x^0, y^0, b^0, y^k, y^l, b^k, b^l) = \frac{Qy\ (x0,b0,yk,yl)}{Qb\ (x0,y0,bk,bl)} \quad (12)$$

Therefore, computed index evaluates environmental performance based on the ratio of good to bad outputs for k,1.

Data and variables

Used statistical information in present study is extracted from information between 1994 through 2007 in Iran. The resources of such information are World Bank and Iranian Central Bank. Utilized variables include GDP (computed based on US dollar value) as a good product, CO_2 emission (thousand tons) as bad product, total manpower (persons) and consumed energy (thousand tons of oil) while manpower and consumed energy are production inputs. Used polluters have the highest share among all polluters. CO_2 is the most important source of global warmness and main volume of its emission is due to consuming fossil fuels. Concerning high consumption of fossil fuels in Iran, we use it as an affecting variable.

CONCULSION

Table 1. Iranian descriptive statistics (1994–2007)

Variable	Descriptions	Unit	Average
GDP	Gross Domestic Production	Million US Dollars	136947
CO_2	Carbon dioxide emission	Thousand tons	363371
EU	Consumed energy	Thousand tons oil	129375
TL	Total labor force	Thousand persons	22767

Table 2. Iranian numeric indices (1994–2007)

Year	Good product index	Bad product index	Environmental performance index
1994	1.047	1.211	0.864
1995	1.307	0.928	1.408
1996	1.186	0.980	1.210
1997	0.934	0.995	0.987
1998	0.900	1.004	0.896
1999	0.977	0.960	1.017
2000	0.943	1.01	0.933
2001	1.053	1.004	1.048
2002	0.961	1.001	0.960
2003	1.096	1.004	1.091
2004	1.126	0.989	1.138
2005	1.141	0.978	1.166
2006	1.103	1.073	1.027
2007	1.225	0.982	1.247
Average	0.90	0.85	1.07

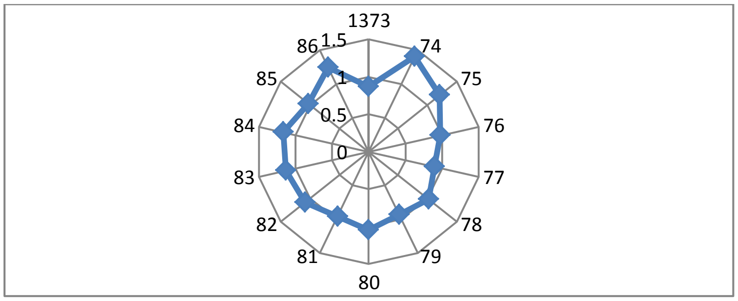

Figure 1. Iranian Environmental performance (1994 – 2007)

Above tables and Figure extracted by abovementioned methodology show Iranian environmental performance between 1994 through 2007. As seen, the fluctuation of Iranian environmental performance results is in an interval in which 1 is the center and it is not a proper value for environmental performance. As seen in Figure 1, the fluctuation of environmental performance is between 0.86 and 1.4. Within this period, Iranian GDP increased to US$286 billion in 2007 from US$60 in 1994 which shows 300% increase. CO_2 emission is increased to 496 million tons from 296 million tons in 1994 which shows a 67% increase. GDP and CO_2 trends indicate that CO_2 emission is not homogenous to GDP growth. The main reason is the most GDP increase is due to extraction and production of raw materials (crude oil) and consuming goods. Labor force is normally grown per annum and no jumping growth is seen.

This is also true for energy growth. However, there are many factors that impact on environmental performance sequentially and we mention the most important ones. Table 2 indicates that the peak of Iranian environmental performance index is seen in 1995. A glance to Iranian economic transformations in 1994 and 1995 indicates that Iranian GDP increased to US$90 billion in 1995 from US$67 billion in 1994 (+35%). Likewise, 1995 is the only year in which CO_2 emission is decreased. Such negative growth is the main reason of Higher Iranian environmental performance index in this year. CO_2 emission decreased to 284 million tons in 1995 from 296 million tons in 1994 (-4%). One should note that in 1994, we witnessed domestic policies especially in foreign exchange market which yield to a 49% inflame in 1995.

The lowest environmental performance index is seen in 1994. Noteworthy, the value of environmental performance index was 0.89 in 1998. Since the highest value is in 1995, it creates an interesting statistics in 1994. In 1994, we observed US$7 billion increase in Iranian GDP as well as 70 million tons increase in CO_2 which is the highest increase in CO_2 within this period. Such huge increase is the main reason of low environmental performance index in 1994. Therefore, as one can observe, more movement toward higher production with lower emission would result in better environmental performance index which requires proper economic policies, using state-of-the-art technologies, utilizing new energies rather than fossil fuels and so on.

REFERENCES

Bian Y, Yang F. 2010. "Resource and environment efficiency analysis of provinces in China: A DEA approach based on Shannon's entropy." Energy Policy 38.

Charnes A, Cooper W, Lewin A, Seiford L. 1994. "Data Envelopment Analysis-Theory, Methods and Applications." Kluwer Academic Publishers, Boston.

Charnes A, Cooper W, Rhodes E. 1978. "Measuring the efficiency of decision making units." European Journal of Operational Research 2: 429–444.

Chung Y, Fare R, Grosskopf S. 1997. "Productivity and undesirable outputs: a directional distance function approach." Journal of Environmental Management 51 (3): 229–240.

Coeli T, Rao D, O'donnell C, battese G. 1998. "An introduction to efficiency and productivity analysis."

Cooper W. Thompson R. Thrall R. 1996. "Extensions and new developments in DEA." Annals of Operations Research 66: 3-45.

Emami Meybodi A. 2005. "The principles of measuring efficiency and productivity." Commercial Study and Research Institute, 2nd edition.

Esty D, Levy M, Srebotnjak T. Sherbinin A. 2005. "Environmental Sustainability Index: Benchmarking National Environmental Stewardship." Yale Center for Environmental Law and Policy, New Haven, Conn.

Fallah M. 2007. "Assessing the efficiency in insurance company branches by DEA." Insurance World News 115 & 116: 18 – 24.

Fare R, Grosskopf S, Hernandez-Sancho F. 2004. "Environmental performance: an index number approach." Journal of Resource and Energy Economics 26: 343–352.

Fathi Hafshajani K. 2008. "Developing DEA to evaluate the efficiency of decision making units." Azad Islamic University

Khajavi S, Salimifard A. Rabieh M. 2005. "Using DEA in determining the portfolio of most efficient admired companies in Tehran Stock Exchange." Shiraz Human and Social Sciences Journal 2.

Wang Y, Greatbanks R, Yang J. 2005. "Interval efficiency assessment using data envelopment analysis." journal of Fuzzy and Systems 153: 347-370.

Zoha P, An B, Poh K. 2006. "Measuring environmental performance under different environmental DEA technologies." Department of Industrial and Systems Engineering, National University of Singapore.

Zhou L, Poh K, Beng W. 2006. "A non-radial DEA approach to measuring environmental performance." European Journal of Operational Research 178: 1-9.