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Environmental productivity growth of selected Iranian economic sectors: A Malmquist approach

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Abstract Evaluation of environmental efficiency has recently attracted an increasing interest. This paper focuses on environmental efficiency analysis and productivity growth of the economic selected sectors in Iran. These sectors are agriculture, oil, industry, transportation and domestic, commercial and public over the period 1997- 2014. For estimation environmental efficiency, data envelopment analysis (DEA) which is a mathematical programming based approach is used and to review the progress or regress environmental efficiency of each economic section Malmquist index is utilized. Labor and capital stock are used as inputs. Value added is considered as a desirable output and CO2 emissions as undesirable output. The empirical results show that the transportation sector survive a low level of environmental efficiency and agriculture and oil sectors have a good situation in this term. According to the results of growth analysis in selected sectors, despite fluctuations in different years, the average total factor productivity is generally associated with an increase. The largest increase productivity for the 1999-2000 can be seen in the oil sector, despite its technical efficiency in the overall economy swings for the whole period, there was not much change.

Keyword: Technology Transfer, Development of Oil Fields, Strategy, Contingent Effectiveness Model, Upstream Oil.

1 Introduction

One of the major problems of the recent decades is environment disaster caused by human activities. In recent decades, environmental problems are increasing. Environmental degradation directly affects the human life, and it is a serious threat to the human life. One of the most important sources of environmental damages is CO2 emission. The economic sectors with high level of CO2 generation have devastating effects on the environment that emphasizes a serious attention on these sectors. On the other hand, countries have targets to achieve economic growth. But, developing countries to achieve growth goals are faced with the problem of environmental degradation. Thus, the economic development as a focus of economists and policy makers is taken into consideration. Mei and Zhang [1] examined environmental efficiency for various regions in China. An empirical analysis of regional environmental efficiency is carried out incorporating sulfur dioxide emission and the

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chemical oxygen demand (COD) of Chinas regions from 2000- 2011. Results indicate that excessive emission pollution is the major cause of environmental inefficiency. Song et al [2] used DEA model with slacks- based measure (SBM) and used them to evaluate the changes in the environmental efficiency of the transportation sector in 30 Chinese provinces between 2003 and 2012. Transportation was found to be inefficient in most of the provinces and the average environmental efficiency was low (0.45). Zhang et al [3] used DEA framework to investigate energy efficiency in 23 developing countries. Only seven countries show little change in energy efficiency during the period of 1980- 2005. Mukherjee [4], examined the energy use efficiency of seven US manufacturing sectors with DEA method for the period 1970 through 2001. The classical DEA models have a weak point that they can only study energy performance within a cross- sectional framework and not over time. It is therefore worthwhile to develop a tool for a time- series analysis of energy efficiency. Malmquist productivity index does this aim. In recent years, Malmquist index has become the standard DEA approach to measure dynamic productivity. Lv et al. [5], focused on the regional level of energy efficiency change in China. They examine total factor energy efficiency for 30 Chinese provinces over the period 1998- 2009 using Malmquist index method and Tobit analysis. The Malmquist estimation results suggest there is a dropping change trend of energy productivity growth. Zhag et al [6], proposed a non- radial Malmquist CO2 emission performance index (NMCPI) for measuring dynamic changes in total- factor CO2 emission performance over time. NMCPI could be decomposed into an efficiency change (EC) index and technological change (TC) index. Based on proposed indices, the dynamic CO2 emission performance change and its decompositions of the Chinese regional transportation industry from 2002 to 2010 are investigated. The empirical results demonstrate that the total- factor carbon emission performance of the transportation industry as a whole decreased by 3220.8% over the period, and this reduction was primarily caused by technological decline. Zhang and Wang [7], proposed an alternative parametric meta-frontier productivity approach called the deterministic parametric meta-frontier Luenberger Productivity Indicator (DPMLPI) for measuring environmentally indicator sensitive productivity growth incorporating technological heterogeneities. The DPMLPI can be decomposed into efficiency change, technological change and productivity growth gap. The parametric linear programming technique is used to estimate parameters and construct the metafrontier. An empirical study for the Korean fossil fuel power industry at the plant- level is conducted for the 2003- 2011 period. The results show a 0.15% increase in environmentally- sensitive productivity growth, which is mainly driven by environmental technological change. Zhou et al [8], employed the Malmquist index to explore total factor carbon emission performance of the words 18 top CO2 emitters from 1997 to 2004.

In this study we apply the Malmquist index environmental efficiency to estimate and track the environmental productivity growth. This study examines environmental efficiency and productivity growth of Iranian economy selected sectors using DEA and associated Malmquist index. The rest of the paper is organized as follows. The next section mainly presents the methods consist of DEA approach and the Malmquist index models used in the study. Section 3 describes the data and variables and performs an environmental efficiency analysis of each sector statically. Environmental productivity growth, convergence analysis and analysis influencing factors on environmental efficiency are also performed in this section. A brief summary, conclusions, further discussion and some suggestions for policy makers are provided in the last section.

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2 Research methodology

2.1 Data envelopment analysis

DEA approach can be easily applied to a multiple input- output framework. This is one of the most advantages of this technique versus parametric method that cause it to be widely used to efficiency and productivity analysis. The technical efficiency score under the DEA framework reflects the ability to obtain maximal output from a given inputs, or reduce the input without sacrifice the output. It is calculated by the relative distance to the "best practice" production frontier by mathematical programming methods. It has been used in comparing efficiency across companies in manufacture sectors across regions [9, 10]. In DEA literature we are interested in increasing outputs and decreasing inputs as much as possible. Considering a general production technology of $T=\{(x,y): \text{x can produce y}\}$ and assuming constant returns to scale for this technology and the radial distance of $D(x,y)=\min\{\theta>0:(\theta x,y)\in T\}$ we get the following model that assess the technical efficiency of *k*-th decision making units (DMUs).

$$
\begin{aligned}
& TE_k = Min\,\theta \\
& s.t., \\
& \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{ik} \qquad i=1,2,\ldots,m \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rk} \qquad r=1,2,\ldots,s \\
& \lambda_j \ge 0, \qquad j=1,2,\ldots,n
\end{aligned} \tag{1}
$$

Where x_{ij} is *i*-th input of *j*-th unit and y_{rj} is *r*-th output of *j*-th unit. Recently, it has also gained popularity in environmental performance measurement due to its empirical applicability. The common procedures for applying DEA to measure environmental performance are to first incorporate undesirable outputs in the traditional DEA framework, and then calculate the undesirable outputs orientation (environmental) efficiencies. However, in some cases produced outputs are not desired to be increased. CO2 is one of this type of output that are known as undesirable outputs in the literature. Thus, we would like to have as less as possible undesirable outputs. In other words, we may treat undesirable outputs as desirable inputs as follows:

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$$
\begin{aligned}
& TE_k = Min\ \theta \\
& s.t., \\
& \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{ik} \qquad i = 1,2,...,m \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rk} \qquad r = 1,2,...,s \\
& \sum_{j=1}^{n} \lambda_j x_{hj} \le \theta x_{hk} \qquad h = 1,2,...,p \\
& \lambda_j \ge 0, \qquad j = 1,2,...,n
\end{aligned} \tag{2}
$$

Where the first *s* outputs are assumed to be desirable and the rest of output are undesirable. Observe that undesirable outputs are treated as input somehow, i.e., less is better.

2.2 Multiple year analysis and Malmquist index

Generally, DEA models are applied to cross- sectional data. As a result, the efficiency is obtained for specific time- period but how efficiency varies time is not known [11]. Malmquist index, the most widely used in frontier analysis, can counter above weakness with the objective of quantifying the evolution of productivity over a period of time. Following Seo et al [12], a Malmquist index approach can be used with non- parametric method for measuring productivity growth that allows for decomposition in terms of efficiency change and technological progress. We consider each sector as a DMU in each year. And then use the improved DEA model of (1) to build the best performance of energy efficiency in the frontier in each period.

Let $x^t \in \mathbb{R}_+^m,\ y^t \in \mathbb{R}_+^s$ be *m*-dimension input and *s*-dimension output vector in period of *t*. Thus, we may have the following production technology in period of *t*.

$$T^t = \{(x^t, y^t) : \text{x}^t \text{ can produce } \text{y}^t\}$$

Suppose that production technology has the convexity and strong disposability of inputs, hence, an output- orientation distance function can be constructed as:

$$D^t(x^t, y^t) = \min\{\theta > 0 : (\theta x^t, y^t) \in T\}$$

For inefficient unit we have $D_o^t(x^t, y^t) < 1$ and for efficient unit that are located on the frontier we have $D_o^t(x^t, y^t) = 1$

With the help of distance function, a Malmquist index in the period of *t* can be shown as [13]:

$$M^t = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \tag{3}$$

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The same, in period of *t+1*, we have:

$$M_o^{t+1} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \tag{4}$$

One may use the following mixed index that is geometric mean of above indices:

$$M_o^t(x^t, y^t, x^{t+1}, y^{t+1}) = \{M_o^t \times M_o^{t+1}\} = [\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \times \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}]^{1/2} \tag{5}$$

The following interesting decomposition can also be utilized to track the effects of efficiency changes and technical changes:

$$M_o^t(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad \text{(Efficiency Change)} \tag{6}$$

$$\times[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}] \quad \text{(Technological Change)} \tag{7}$$

Where the efficiency change measures the catch- up effect and it reflects whether or not a movement towards or away from the frontier has occurred at period t and t+1. Moreover, the technical change component measures the firm- specific effect of the shift of the technology frontier [12], which indicates whether or not DMUs belongs to the frontier have improved or worsened from period *t* to *t+1*.

A value for the Malmquist index greater than one indicates that productivity growth is positive while in the opposite case, productivity growth becomes negative [5].

3 Empirical analysis
3.1 Data and variables

This paper studies environmental efficiency of five selected economic sectors (agriculture, oil, industry, transportation and domestic, commercial and public) as the basic research units during the period 1997-2014. Model (2) is used as the based model with following description. Labor and capital stock of each sector are assumed as two outputs in our analysis. Value added is considered as desirable output and CO2 value is considered as undesirable output in our analysis. Employed labor is considered as the first input that is found from Iran Statistical Yearbook (1997-2014). Capital and net capital stock of each sector is selected as proxy of this input that is reported as billion IRR. Added value of each sector that is desirable output is extracted from the Statistical Center of Iran. CO2 emissions of each sector as undesirable output are extracted from Hydrocarbon balance sheet [14, 15].

Table 1 Descriptive statistics of input-output data

	Mean	StDev	Min	Max
Labor	344404.7	366039.1	16598.1	1589633

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Capital	1084515	1730118	36569	1.22e+07
Added Value	2476521	1494872	104815	4404110
Emission	7.81e+07	4.72e+07	1798253	1.91e+08

3.2 Classical and Environmental efficiency analysis

We construct a production frontier corresponding to different years, respectively, to measure the environmental efficiency of each sector separately for each year using described data set during the period of 1997- 2014. The environmental efficiency of DMUs can be measured on the distance of its actual production point to the production frontier. Table 2 reports this result. Although we have low number of units that are selected economic sections we have rather reasonable discrimination power in the result.

Table 2 Environmental efficiency analysis of five selected sector in period of 1997-2014

Year	Agriculture		Oil		Industry		Transportation		Domestic, commercial and public	
	DEA	E DEA	DEA	E DEA	DEA	E DEA	DEA	E DEA	DEA	E DEA
1997	1	1	1	1	1	0.945	0.433	0.324	0.532	0.515
1998	1	1	1	1	1	1	0.542	0.424	0.577	0.608
1999	1	1	1	1	1	1	0.677	0.537	0.668	0.685
2000	1	1	1	1	0.999	1	0.49	0.377	0.629	0.658
2001	1	1	1	1	0.98	0.853	0.464	0.351	0.624	0.625
2002	1	1	1	1	1	1	0.482	0.397	0.594	0.674
2003	1	1	1	1	0.915	0.796	0.279	0.23	0.483	0.492
2004	1	1	1	1	0.873	0.873	0.255	0.255	0.502	0.502
2005	1	1	1	1	0.742	0.863	0.288	0.269	0.425	0.507
2006	1	1	1	1	0.537	0.695	0.197	0.218	0.325	0.47
2007	1	1	1	1	0.542	0.737	0.214	0.255	0.326	0.979
2008	1	1	1	1	0.699	0.964	0.448	0.583	0.508	0.759
2009	1	1	1	1	0.482	0.766	0.293	0.414	0.369	0.628
2010	1	1	1	1	0.582	0.895	0.344	0.482	0.466	0.767
2011	1	1	1	1	0.494	0.824	0.339	0.479	0.477	0.806
2012	1	1	1	0.999	0.397	0.693	0.246	0.348	0.365	0.633
2013	1	1	1	1	0.581	0.958	0.318	0.446	0.533	0.859
2014	1	1	1	1	0.517	0.813	0.393	0.522	0.451	0.701
Average	1	1	1	0.999	0.741	0.87	0.372	0.383	0.491	0.659

According to the results, agriculture and oil sector are environmentally efficient in average. It means that agriculture and oil sectors produce reasonable output in return of using inputs and producing CO2 emission. The transportation sector has the lowest environmental efficiency score. Thus, this sector could produce the same level of output with lower emission and using less inputs.

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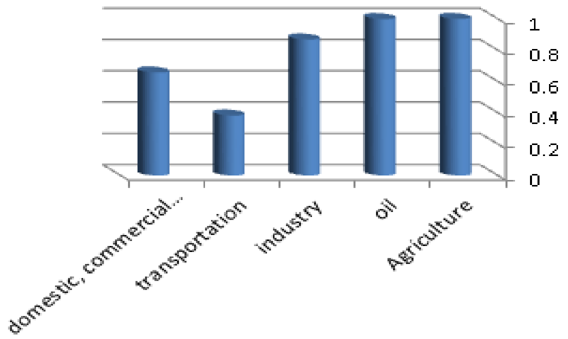

Fig. 1 Average environmental efficiency of selected sectors

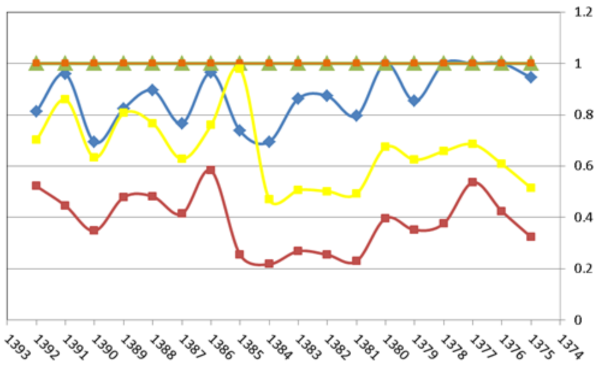

Fig. 2 The trend of environmental efficiency

Green curve: agriculture, **Brown curve:** oil, **Blue curve:** industry, **Red curve:** transportation, **Yellow curve:** domestic, commercial and public

3.3 Environmental productivity growth

In order to investigate the sources of CO2 emission performance changes, the MCPI have been decomposed into efficiency change (EC) and technological change (TC) components. The efficiency change (EC) components results are shown in table 3. The average efficiency change index of CO2 for example transportation sector is 1.081 under our MCPI framework, showing an average annual increase in efficiency of 8.1%. This result indicates that the efficient frontier of agricultural sector has not changed and domestic, commercial and public sector shows an average annual increase in efficiency about 5.2%. The average EC index of oil sector is approximately 0.999 under MCPI, indicating a decrease in the efficiency change of CO2 emission performance.

Table 3 Environmental efficiency changes in period of 1997-2014

Years	Agriculture	Oil	Industry	Transportation	Domestic, commercial and public
1997- 1998	1	1	1.058	1.308	1.18
1998- 1999	1	1	1	1.266	1.126
1999- 2000	1	1	1	0.702	0.96

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2000- 2001	1	1	0.853	0.931	0.949
2001- 2002	1	1	1.172	1.131	1.078
2002- 2003	1	1	0.796	0.579	0.729
2003- 2004	1	1	1.096	1.108	1.020
2004- 2005	1	1	0.988	1.054	1.009
2005- 2006	1	1	0.805	0.81	0.927
2006- 2007	1	1	1.060	1.169	2.082
2007- 2008	1	1	1.308	2.28	0.775
2008- 2009	1	1	0.794	0.71	0.827
2009- 2010	1	1	1.168	1.164	1.221
2010- 2011	1	1	0.92	0.993	1.050
2011- 2012	1	0.999	0.841	0.726	0.785
2012- 2013	1	1	1.382	1.281	1.357
2013- 2014	1	1	0.848	1.17	0.816
Average	1	0.999	1.005	1.081	1.0524

The TC component of MCPI is shown in table 4; it is found that the average TC index of all considering sectors are higher than one, indicating an increase in the technological change of CO2 emission performance. This implies a technological decline in CO2 emission reduction in Iranian selected sectors during the research period. Almost all selected sectors show a state of technological growth under the MCPI. This results propose technological innovation in low- carbon technology within the selected sectors during the sample period.

Table 4 Technology changes in period of 1997-2014

Years	Agriculture	Oil	Industry	Transportation	Domestic, commercial and public
1997- 1998	1.023	0.871	0.987	0.95	1.023
1998- 1999	1.21	0.641	0.999	0.823	1.059
1999- 2000	1.093	1.972	1.244	1.662	1.319
2000- 2001	1.108	1.456	1.303	1.418	1.317
2001-2002	1.027	0.918	1.081	0.991	1.092
2002- 2003	1.238	1.562	1.513	1.824	1.586
2003- 2004	1.061	1.147	1.18	1.531	1.188
2004- 2005	1.109	1.237	1.201	1.203	1.201
2005- 2006	1.079	1.364	1.316	1.379	1.345
2006- 2007	1.142	1.055	1.078	1.018	0.742
2007- 2008	1.189	0.788	0.754	0.581	0.96
2008- 2009	0.899	1.453	1.452	1.695	1.52
2009- 2010	1.149	0.958	0.94	0.866	0.923

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2010- 2011	1.075	1.174	1.111	1.303	1.261
2011- 2012	1.109	1.239	1.206	1.494	1.424
2012- 2013	1.244	0.85	0.75	0.807	0.922
2013- 2014	1.236	1.218	1.16	1.624	1.466
Average	1.117	1.170	1.133	1.245	1.196

Table 5 shows the MCPI estimations. The MCPI results indicate an increase in the total-factor CO2 emission performance for the period of 1997 to 2014. The average MCPI index for example, agriculture sector is 1.117. This result means that on average, the ratio of target carbon intensity to actual carbon intensity increase by 1.1% per year over the sample period.

Table 5 Environmental productivity growth of economic selected sectors in period of 1997-2014

Year	Agriculture	Oil	Industry	Transportation	Domestic, commercial and public
1997- 1998	1.023	0.871	1.044	1.242	1.207
1998- 1999	1.21	0.641	0.999	1.041	1.192
1999- 2000	1.093	1.972	1.244	1.166	1.266
2000- 2001	1.108	1.456	1.111	1.32	1.249
2001- 2002	1.027	0.918	1.266	1.12	1.177
2002- 2003	1.238	1.562	1.204	1.056	1.156
2003- 2004	1.061	1.147	1.293	1.696	1.211
2004- 2005	1.109	1.237	1.186	1.266	1.211
2005- 2006	1.079	1.364	1.059	1.116	1.246
2006- 2007	1.142	1.055	1.142	1.19	1.544
2007- 2008	1.189	0.788	0.986	1.324	0.744
2008- 2009	0.899	1.453	1.152	1.203	1.257
2009- 2010	1.149	0.958	1.097	1.008	1.126
2010- 2011	1.075	1.174	1.022	1.293	1.324
2011- 2012	1.109	1.237	1.014	1.084	1.117
2012- 2013	1.244	0.85	1.036	1.033	1.251
2013- 2014	1.236	1.218	0.983	1.9	1.196
Average	1.117	1.17	1.108	1.238	1.204

4 Conclusion and further discussion

This paper investigates the environmental efficiency and productivity growth of five Iranian economic sectors. The agriculture sector is most efficient compared to other sectors and transportation sector is inefficient. It means that agriculture sector uses maximum of its resources with environmental Considerations. The average environmental efficiency is 0.383, the results reflect the real situation of Iran. Thus, there exist a long way of improving this

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sector from environmental point of view. Using better resources in term of producing emission can be of the first solution to this case. Utilizing more advanced technology and machinery that more friendly with environment is a generic solution for all sectors, especially for industry and transportation. The highest amount of average environmental efficiency related to the agriculture sector, because we apply as environmental efficiency measuring indicator. Note that this result is based on our analysis that we consider only CO2 as a proxy of emission. The average efficiency changes show an average annual increase in efficiency. The average technological change of all selected sectors shows an average annual increase in technology. However, as mentioned before the result shows that we are almost in right track but we have a long way to reach the goals.

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