**Applied Economics Studies, Iran (AESI)** 20

Volume 8, Number 30, Summer 2019

# Energy efficiency and the abatement cost of marginal carbon dioxide emission in Iranian cities

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## Abstract

One of the major challenges governments are facing in the 21st century are environmental crises. Detection of destructive factors, measuring the costs degrading the environment and managing their deteriorating factors play an important role in maintaining this unique wealth. The main objective of this study is to measure the energy efficiency and final cost of reducing carbon dioxide in urban areas of Iran's provinces. This study was carried out using time series data gathered between 2006 to 2016. According to the Ministry of the Interior of the Islamic Republic of Iran’s classification, each province of the country fits into exactly one of the five specified regions. Regions defined based on neighboring factors, geographic location, and commonality. This research has been done using mathematical modeling programing.

The results of this research illustrate that the average energy efficiencies of regions 3, 2, and 5 are above the average energy efficiency of the total regions of the country and regions 1 and 4 average energy efficiencies are below that. The 3rd region with the efficiency of 0.93 has the highest, region 4 with a score of 0.61 has the lowest energy efficiency and region 1 has the highest carbon dioxide emission in the regions. The 3rd with the highest energy efficiency has the lowest carbon dioxide emission.

The average relative price of carbon dioxide emission in all regions is 21.5 ten thousand Rials per ton. The average shadow value of the pollution in all regions based on the desired product is 194.4 ten thousand Rials per ton.

**Keywords**: Energy efficiency, Carbon dioxide emission abatement cost, shadow price of pollution.

**JEL Classification**: Q51, Q52, Q43.

## 1. Introduction

Fast development of economy along with quick process of urbanization has culminated in great use of energy and relevant CO2 release (Wang, Lv, Bian, & Cheng, 2017).

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Mean growth of Iranian total population (2006-2016) was 1.27%; the growth of households was 3.2%, and primary energy supply per capita (barrels per person) was 2.19% while the mean growth (2006-2016) of the final per capita consumption (barrels per person) was 0.89% (hydrocarbon balance sheet of Iran, 2018). If energy efficiency is defined simply as the ratio of the final demand to the initial supply, then the mean energy efficiency of Iran can be roughly estimated at 40% (Institute for International Energy Studies, 2016).

For decades, human beings have encountered global warming, which poses a great threat to the existence and expansion of human community. The Climate Vulnerability Monitor report indicated that variation in weather conditions mainly because of carbon dioxide ($CO_2$) release, accounts for almost 400000 fatalities and 1.2 trillion dollars of annual economic damage. This is equivalent to 1.6% of the world Gross Domestic Production (GDP). As a consequence, efficient control and decrease of CO2 release is now among the top global priorities.

In most of cases, CO2 is not an ideal output; decrease of CO2 release is not free of expenses. In practices, the major problem of policy-makers includes minimizing CO2 emissions and its reduction expenses, while at the same time doing manufacturing activities and enhancing economic abatement. Calculating CO2 abatement costs (CAC) can assist states and companies in taking logical political choices. CAC presents significant reference points for establishing emission decrease rules and targets. The expense of emission reduction is fundament for world climate talks. Methods of calculating CAC can be categorized into three categories: bottom-up methods, top-down methods, and hybrid methods. Top-down methods are classified into two different groups: the distance function method and the computable general equilibrium (CGE) model. From Hourcade et al.'s (2006) viewpoint, a combination of bottom-up and top-down methods may be used to establish hybrid methods. Differences in methods and models could affect the estimation of specific expenses of CO2 decrease (Wang, Wang, Hang, Zhao, & Ge, 2018).

One may consider Marginal abatement cost (MAC) caused by directional distance function approach as the opportunity cost of decreasing one extra unit of pollutant release given the relevant more consumption of inputs or less manufacturing of appropriate outputs. Although MAC is not an ideal criterion for evaluating climate laws, the calculation of MAC can provide a reference for rule makers to develop more efficient laws on energy and environment, including environmental tax system and release trading systems.

Shephard for the first time suggested distance function approach, which was further extended by Färe et al. This approach is known as a proper criterion for calculating the efficacy and estimating the MACs of undesirable outputs by employing the notion of shadow price. Generally, nonparametric or parametric technique may be used to calculate the distance function and MACs (shadow price). Nonparametric technique does not have a functional form for the basic technology over the course of the calculation, while the parametric techniques do.

Data envelopment analysis (DEA) is a very popular nonparametric method. It calculates the distance function and MACs from a more integrated perspective (Tang, Yang, & Zhang, 2016).

## 2. Efficiency assessment approach

Suppose that Iran has *n* independent cities, referred to as $\mathrm{CUj}$ $(n = 1, 2, \ldots, j)$. In manufacturing process, every city employs several inputs such as labor, capital and energy, represented by $XL_j$ , $XK_j$ and $XE_j$ $(n = 1, 2, \ldots, j)$ , respectively, to generate GDP ($YG_j$) together with $CO_2$ releases ($YC_j$).

$$\rho_0 = \min \frac{1 - {}^{1}\!/_{3}\,\left(\frac{s^{l-}{}_0}{xl_0} + \frac{s^{k-}{}_0}{xk_0} + \frac{s^{e-}{}_0}{xe_0}\right)}{1 + {}^{1}\!/_{2}\,\left(\frac{w_g s^{g+}{}_0}{yg_0} + \frac{w_c s^{c-}{}_0}{yc_0}\right)}$$

$$\sum_{j=1}^{n} \lambda_j xl_j + s^{l-}{}_0 = xl_0$$

$$\sum_{j=1}^{n} \lambda_j xk_j + s^{k-}{}_0 = xk_0$$

$$\sum_{j=1}^{n} \lambda_j xe_j + s^{e-}{}_0 = xe_0$$

$$\sum_{j=1}^{n} \lambda_j yg_j - s^{g+}{}_0 = yg_0$$

$$\sum_{j=1}^{n} \lambda_j yc_j + s^{c-}{}_0 = \left(1 + \frac{s^{g+}{}_0}{yg_0}\right) yc_0$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j, s^{l-}{}_0, s^{k-}{}_0, s^{e-}{}_0, s^{g+}{}_0, s^{c-}{}_0 \geq 0, j = 1,2 \ldots, n. \qquad (1)$$

$s_0{}^{l-}$, $s_0{}^{k-}$, $s_0{}^{e-}$, $s_0{}^{g+}$ and $s_0{}^{c-}$ refer to slack variables In model (1), which are respectively relevant to labor, capital, energy, GDP and CO2. The subscript “0” refers to the urban area that needs to be assessed. $\lambda_j$ shows the variable of intensity and displays how much $CU_j$ is engaged in the manufacturing process. Remember that model (1) is analogous to the classic slacks-based measure of efficiency based on the SBM auxiliary variable with the exception of its final constraint. This constraint realizes the weak disposability undesirable outputs hypothesis, which has been mentioned in the following sections (Wang, Lv, Bian, & Cheng, 2017).

Given that model (1) is a non-linear programming, it can be converted into a linear model.

## 3. Cities, variables and data sources

This study focused on Iranian urban areas during the period from 2006 to 2014. The Geographical Map of the Ministry of State published in 2014 was used[1].

The variables required for carrying out the study, the source of data related to these variables, as well as the method of data collection and calculation related to them are presented here.

Labor force: For this variable, the statistics on the active population (only the working population) for each province were collected from the Iranian Statistics Center. Capital inventory: Capital to production ratio is used to calculate the capital stock of each province.

Energy consumption: energy consumption, 8 types of fuel (liquid gas, aviation fuel, gasoline, kerosene, diesel fuel, mazut, natural gas and electricity consumption) with different measuring units were gathered from the Iranian Statistics Center for each province. Subsequently, they are converted into similar units (British thermal unit, million BTUs); the converted units were taken from the British Petroleum Company (BP).

Carbon Dioxide Emission: For calculation of carbon dioxide emissions in each province, the following formula was used:

$$\mathrm{CE_{ff}} = \sum_{i=1}^{nfc}(\mathrm{FC_i} * \mathrm{EF_i}) \quad (2)$$

Where $FC_i$= represents the total thermal value of i-th type fossil fuels with British thermal units (million BTUs), $EF_i$= shows the emission factor of i-th fossil fuels with tonne of carbon dioxide per million BTU, $N_{fc}$= denotes the number of all consumed fuels, and

$CE_{ff}$= is the total CO_2 emissions due to fuel consumption

GDP: Gross Domestic Product Statistics at Market Price and Retail Price Indicator for each province were collected from the Iranian Statistics Center and the actualization of data was done as a ratio of GDP at retail price index.

GDP: GDP is derived from the value-added ratio for each province, which is collected from the Iranian Statistics Center, to the value of each province's

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[1] Categorization of districts has been done in the light of distance, geographical location and commonalities. This categorization is as follows (Ministry of State, 2014):

District 1: Tehran, Qazvin, Mazandaran, Semnan, Golestan, Alborz, Qom

District 2: East Azarbaijan, West Azarbaijan, Ardebil, Zanjan, Gilan, Kurdistan

District 3: Kermanshah, Ilam, Lorestan, Hamedan, Markazi, Khuzestan

District 4: Isfahan, Fars, Bushehr, Chaharmahal Bakhtiari, Kohgiluyeh and Boyer Ahmad, Hormozgan

District 5: Khorasan Razavi, Southern Khorasan, North Khorasan, Kerman, Yazd, Sistan and Baluchestan intermediate consumption, also collected from the Statistics Center for all provinces.

Pollution Price: In this study, the cost of pollution is $ 13 for 2018, as indicated by the World Bank[1].

## 4. Conclusions

Based on the objective function of the research model, which shows energy efficiency, district 3 including Kermanshah, Ilam, Lorestan, Hamedan, Markazi and Khuzestan provinces has higher energy efficiency compared to district 1, 2, 4 and 5. The mean energy efficiency rating in the five districts of Iran shows that district 2, 3, and 5 are above the mean and districts 1 and 4 are below the mean. Finally, the study finds that district 3 with a score of 0.93 has the highest energy efficiency and district 4 with a score of 0.61 the lowest energy efficiency. District 1 has the highest carbon dioxide emissions among the districts, and district 3 has the highest energy efficiency with minimum carbon dioxide emission rate.

The mean relative shadow price of carbon dioxide emissions is as follows: In district 1, the shadow price is 25.6, which is the highest among the districts, because in district 1, carbon dioxide emissions were higher than all other regions. District 2, in terms of shadow price, was the second, and district 5, 4 and 3 were respectively third, fourth and fifth.

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[1] This price is based on the mean carbon price in the European carbon market, US carbon market and carbon value in the energy balance sheet in 2018.