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Proposing an extended model of dynamic data envelopment analysis using goal programming to calculate relative efficiency of industrial development in provinces of Iran

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Abstract

The purpose of the present study was to provide a dynamic model of data envelopment analysis by utilizing from goal programming based on variables of population and education in order to evaluate the relative efficiency of industrial development in provinces of Iran during the years 2007 to 2016. For this purpose, the demographic, education and industry development variables were firstly determined with the help of 42 university and industry experts, then the research model was developed which included: objective function in the form of minimizing adverse deviations of goal constraints based on variations of units at different time periods, and model constraints in the forms of goal constraints and system constraints. In the next step, the model was solved through GAMS Software after designing and implementing dynamic and goal models of data envelopment analysis for provinces of the country in the mentioned period. The relative efficiency of industries development of the provinces was separately calculated for each of the understudy years, then the obtained values were used to calculate the relative efficiency of industry development for each province. According to results, Khuzestan province was ranked first and Sistan and Baluchistan province ranked last in term of average relative efficiency.

Keywords: Industries Development, Population, Education, Data Envelopment Analysis, Dynamic Data, Goal Programming
2010 MSC: 90C08, 94A16

1 Introduction

Nowadays, most scholars emphasize on the belief that the engine of comprehensive development of societies and countries is their industrial and productive progress or in other words, development of their industries accompanied by innovation [3]. Reviewing the historical course of industrial development ideas indicates that these ideas have an emphasis on the development of a science-based industry and believe that no country will succeed in pursuing a rapid path to industrial development without being in the forefront of science and innovation. One of the aspects of innovation is efficiency development in performance which itself considered as an indicator for development and progress. In the simplest conceptual structure, efficiency is a term that means the output to input ratio. When an

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industry can keep its output higher than its input, it is more efficient. But the important matter is that there is no unique definitive and complete indicator for measuring a single industrial unit so that it can be used to modify all of the industrial units. Perhaps the reason is that inputs and outputs are not consistent in all units over time and therefore, the efficiency criterion is uncertain due to the existing changes. Therefore, the concept of efficiency has been defined in a relative form based on the performance of other units, which its mathematical form is called Data Envelopment Analysis (DEA) [6]. This model has made a lot of progress since its introduction, but researchers of this area have not yet been able to find a solution to overcome changes in the model.

According to previous studies, the main problem of utilizing efficiency as a criterion for evaluating industrial development is the fact that the concept of development can only be defined over time. Hence, a simple DEA model cannot be used to achieve development goals. Considering differences between the number and type of model variables in different industries and conditions, the dynamic structure cannot only meet the goals but a goal model can be used to strengthen the work. On the other hand, it is necessary for investigators to examine the efficiency of the provinces' industrial development in the past, present and future times. According to preliminary studies and experimental samples, the dynamic model of DEA method has been implemented in a few special cases, but the important point is that this model should be so that makes it possible to calculate the relative efficiency of units at different times with a single model. Therefore, a dynamic-based DEA model should be obtained for development of industries in provinces of the country by using goal programming in theoretical viewpoint, which can make it possible to calculate the relative efficiency of all provinces at different times with a single model. In the present study, the above-mentioned model has been firstly proved and then tested on a case study of an industrial community of the country. On the other side, the industrial development status of provinces of the country has been examined using results of the model and presenting the function in the past, present and future times. For this purpose, the function was firstly proved for $n+1$ certain time and then tested on a sample of the statistical population. If the gap of previous studies is paid attention in the applied viewpoint, it becomes clear that it is necessary for industrial development programming in provinces of the country to investigate the performance of the provinces in terms of industrial development in past years and utilize from the results for future and prediction of the future situation. This issue has been also addressed in the present study. Therefore, the main question of the present study was that: how is the extended model of dynamic envelopment analysis data using goal programming for calculation of relative efficiency of industrial development in provinces of the country? According to this question and considering purposes of the present study, the sub-questions have been posted and discussed as follow:

1. What are the selected indicators (input and output) to determine the level and position of industrial development of the provinces in demographic and educational dimensions?
2. What is the mathematical model of dynamic data envelopment analysis using goal programming?
3. How is the relative efficiency of the provinces in term of industrial development from 2007 to 2016?
4. What is the rank of each province of the country in term of industrial development?

2 Research Background

Tavan and Salehi [20] conducted a study to investigate a new model for ranking suppliers through Grey Relational Analysis (Grey Relational Analysis (GRA), also called Deng's Grey Incidence Analysis model, and was developed by a Chinese Professor Julong Deng of Huazhong University of Science and Technology. It is one of the most widely used models of Grey system theory. GRA uses a specific concept of information [15]). (GRA) and uncertainty-based data envelopment analysis. It was argued in the study that organizations must increase the outsourcing of their activities and focus on their core capabilities due to the business environment and intensive competition of domestic and abroad markets. In the study, a mathematical model was also proposed for evaluating and selecting efficient suppliers using GRA and uncertainty-based data envelopment analysis. Given the desirable results obtained from solving numerical examples, it has been recommended to utilize from the proposed model in uncertainty conditions [19]. In their study, Omrani and Shafaat [14] utilized from a combination of data envelopment analysis and cooperative game theory to evaluate and rank the units in the term of satisfaction. In the study, each unit was considered as a player and enters the coalition with other players in order to increase its desirability. After calculating the players' coalition revenues, each player's value was obtained through Shapley value formula (The Shapley value is a solution concept in cooperative game theory. It was named in honor of Lloyd Shapley, who introduced it in 1953. The Shapley value is characterized by a collection of desirable properties). Finally, a numerical example was used to rank seven Iranian airlines in 2013 to confirm the accuracy of the model [13]. Razavi et al (2015) conducted a study to evaluate the innovative performance of knowledge-based companies using network-based data envelopment analysis in game theory approach. In the study, network-based data envelopment analysis of game theory approach was used to determine the total efficiency and stages and the modeling was carried out through the leader-follower method (Stackelberg game; The Stackelberg leadership model is a strategic game in economics in which the leader firm moves first and then the follower firms move sequentially). After solving the model, the obtained results showed that the total relative efficiency of all companies was less than one and only two companies from thirty-eight companies were completely efficient in the first stage. Also in the second stage, only three companies were completely efficient [16].

Azar et al (2014) conducted a study on investigating the productivity of bank branches (one of the banks in Guilan province) using network data envelopment analysis. In the study, the approach of network data envelopment analysis was used to design a measurement model for units which included interactive and dependent stages. Finally, the proposed method was used to measure efficiency, effectiveness, and productivity of branches of one the banks in Guilan province in different processes and levels. One of the interesting results of this study was that the most efficient branch with the most effective branch is not necessarily the best branch in terms of productivity [1]. In their study, Shah Tahmasbi et al (2013) utilized from data envelopment analysis to evaluate the relative efficiency of Iran's provinces in the term of economic indexes of culture during the third and fourth development programs. The study was conducted using 11 indicators and taking into account all provinces of the country during the years of 2000-2007 in order to investigate the efficiency of provinces in the field of economic aspects of culture. The important point in comparing the efficiency of provinces in the third and early years of fourth development program was a high degree of variability in the amount of efficiency during these two programs, which can be due to the instability in cultural policies and lack of a suitable planning in this regard. This approach is more recognizable among inputs [18]. Bastani et al (2014) conducted a case study automotive industry to provide an integrated model for allocating products to distributors in the supply chain using data envelopment analysis and goal programming. For this purpose, the related goals and criteria for evaluating distributors were first identified and then the important criteria were selected. To continuing the efficiency scores of distributors were calculated through data envelopment analysis method. Finally, the integrated model was used to determine the distribution of products between distributors based on maximizing the efficiency and taking into account existing goals [2].

Tavana et al (2016) conducted a study to calculate the relative efficiency of units with respect to changes in data during the evaluation period. In the study, it was argued that sustainable supplier evaluation is one of the most complex tasks in sustainable supply chain management (SCM). The proposed model was a combination of goal programming (GP) and DEA in an integrated and seamless paradigm to determine the future revenue of DMU (supplier). In addition, the role of decision-maker was shifted from past supervision to future planning. The case study of this research indicated the applicability of the proposed model as well as the applicability of the methods and algorithms [20]. In their study, Omrani et al (2016) investigated the efficiency estimation of interdependencies between parts of a company or determining the dependent process of a production system to improve operational efficiency. To explain the capability of the proposed model, this study was conducted for the first time to measure the efficiency of eight Iranian airline routes in several periods related to the transfer of streams. They proposed a dynamic relational model that simultaneously measures the system efficiency and internal processes over time. To demonstrate the capability of the proposed model, the measurement of the relative efficiency of eight Iranian airlines was calculated for the first time in several periods and the obtained results were compared with DEA network model [14]. Olfat et al (2016) conducted a study to investigate the measurement of dynamic network performance in determining the efficiency of airports. The obtained results showed how the development of a dynamic fuzzy network efficiency measurement approach can help to determine the performance of an airport system. For this purpose, two approaches were selected for performance of each airport, which included effective community functions and associated passenger functions. This new combination makes it possible to have a comprehensive evaluation of airports' performance [12].

Oscar et al (2016) conducted a study on a combination of DEA dynamic network technology with traffic engineering and social and behavioral theory to provide useful information and insight for future design with comprehensive strategic management through evaluating the dependence of efficiency among prospects. According to the obtained results, the proposed approach makes it possible for the relative efficiency of prospects to be used where can turn into useful information and facilitate the insight of designing traffic management strategies [8]. Khoveyni et al (2016) conducted a study to investigate the approach that makes it possible for inputs and outputs to be placed in both negative and non-negative domains. In the study, it was recommended that comprehensive integer programming and MIP-DEA (Multi Integer Programming–Data Envelopment Analysis) model can be used to determine the minimum and maximum compaction of DMU (Decision Making Unit). Also, classification of the DEA approach was introduced to determine DMU compaction and lowest DMU aggregation. Finally, a numerical example and an experimental program were presented to a better understanding of the study [10]. Roozbeh et al (2016) conducted a study to investigate a data envelopment analysis-based model. In the study, it has been assumed that DMU is formed by positive and negative inputs and outputs. In the first stage, optimistic and pessimistic models were measured and the scale of production in optimistic and pessimistic models was proposed using negative data. The obtained values were comprised of double-wall boundaries and Hurwicz criteria to obtain DMUs with MPSS (Most Productive Scale Size) [17].

3 Literature and theoretical foundations

3.1 Efficiency

Efficiency represents the concept of how well an organization uses its resources in terms of production in relation to the best performance in a period of time. The efficiency of an enterprise unit (DMU) is obtained through its input-output ratio. An enterprise unit is more efficient when it can create higher outputs with fixed inputs or create fixed outputs with lower inputs or higher outputs with lower inputs [11]. According to the above definition, efficiency is merely a comparison between "expected resources that should be consumed for specific purposes and activities" and "consumed resources". The efficiency based on expected output or standard output value is calculated using below ratio:

$$\text{Efficiency} = \frac{\frac{\text{Real output}}{\text{Real input}}}{\frac{\text{Expected output}}{\text{Expected input}}} = \frac{\text{Real output}}{\text{Expected output}} \tag{3.1}$$

Sometimes, efficiency is calculated with the number of resources used by the organization (enterprise unit) to achieve goals, which its equation is as follow:

$$\text{Efficiency} = \frac{\text{The amount of resources expected to be consumed}}{\text{The amount of really consumed resources}} \tag{3.2}$$

According to the above definition, efficiency is merely a comparison between resources expected to be consumed to achieve specific purposes and activities and really consumed resources. Therefore, efficiency is the performance criterion of an organizational system in relation to the number of resources (inputs). Efficiency is the number of resources used to produce a certain amount of product. The concept of efficiency is often misunderstood by the words of effectiveness and productivity. Effectiveness represents the degree to which activities of an organization are consistent with pre-determined goals or the degree to which goals are achieved. But productivity is a combination of effectiveness and efficiency because effectiveness is related to the performance and efficiency of resources. In the definition of productivity, these concepts are expressed as follow [5]:

$$\text{Productivity Index} = \frac{\text{Gained output}}{\text{consumed input}} = \frac{\text{gained performance}}{\text{Consumed resources}} = \frac{\text{effectiveness}}{\text{efficiency}} \tag{3.3}$$

3.2 Performance evaluation through measurement of efficiency

Basically, one of the interested areas of managers is to evaluate the performance of different parts of the organization and measure their efficiency in using input resources and converting them into products and outputs. Performance measurement plays a more important role in comparison with the quantization and accounting process. In public organizations, measuring performance through continuous improvement models can facilitate internal understanding and integration among members of the organization. It can also provide information about the effectiveness of strategies, identification of critical factors of success and potential opportunities [4]. Nowadays, development of technology, the role of critical factors of success in performance, the structure of domestic and global competition, quality advantage, the position of organization and goods and services provided by it to the market and customers are among the factors that should be considered in evaluating performance. Another important point in the literature of performance management is the significant relationship between results of evaluation and data and process evaluation. Today, the prevailing thinking is that the input modification and process of operation logically lead to the provision of appropriate goods and services. Final control of operation cannot indicate the overall performance of organization [7].

The concept of efficiency has a variety of types: the technical efficiency indicates the ability of each firm to maximize production with respect to the sources and factors of production. Allocation efficiency implies generating the best combination of products with the least costly combination of inputs. Economic efficiency is obtained from the product of technical efficiency and allocation efficiency. Structural efficiency of each industry is also derived from the mean weight of efficiency of its companies. Finally, the scale efficiency of a unit is obtained through the ratio of observed effects to the efficiency on the optimal scale [9].

4 Methodology

A present case study is a mathematical analytical research type in the term of analysis and an empirical research type in an experimental term.

4.1 Statistical population and sample size

The statistical population of the present study has been divided into two separate parts according to the data analysis steps.

In the first step, the statistical population included experts with the following characteristics to finalize the input and output variables:

- Having Ph.D. in economics, management, and accounting
- Having a managerial background in the field of planning for provincial industry administration
- Having a history of work or teaching in the field of industrial development

After identifying the input and output variables for data gathering of the second step which was carried out in the form of mathematical modeling and analysis, the data related to development of industries of all provinces in the form of input and output variables were analyzed through a combined model of dynamic data envelopment analysis and goal programming (GP). Therefore, the statistical population of the second step included all provinces of the country. In fact, the basis for analyses of the present study was input and output variables as well as the population, educational and industrial data of the provinces during the years of 2007 to 2016 which gathered from Database of Iranian Statistics Center. The related experts were used to identify input and output variables for development of industry, population, and education of provinces through snowball method. At least, 15 experts participated in this part. But in the second step, the census was performed on all provinces and all necessary information was collected.

In the first step, the snowball method was used for sampling from experts. In this way, the questionnaire was distributed among available experts. After collecting their opinions, those experts introduced new ones to be questioned. This process continued until the time allowed and no other new expert was introduced or until theoretical saturation. The results of each step were evaluated using W. Kendall's rank correlation coefficient (Kendall's W is a non-parametric statistic used to determine the degree of coordination between opinions. If it equals to zero means a complete disagreement and equals to one means a complete agreement). The data panel method was used to obtain data related to all variables. A census was also made in the second step.

4.2 Data Gathering

In the present study, required data were gathered using field and library methods. In this regard, theoretical literature and research background were based on library studies including books, articles, and related sites. Also, a variety of structured and semi-structured interviews were utilized for data gathering. In fact, interviews were conducted to identify variables (inputs and outputs) at the country level. During the research, in addition to interviewing the experts, documentation and reports related to the development of industry, population and education are also used in relation to the variables (input and output).

4.3 Data Analysis

In the present study, three main data analysis methods were used, which have been explained below:

- Delphi method to identify criteria of population, education and industrial development.
- Mathematical modeling method to design a dynamic data envelopment analysis model using GP (goals programming).
- Mathematical modeling method to design relative efficiency function of industries' development in the provinces of Iran.

5 Research Findings

In this section, appropriate answers have been provided for research question through results obtained from analyses. The questions of the present study were about the matter how is the extended model of dynamic envelopment analysis data using goal programming for calculation of relative efficiency of industrial development in provinces of the country?

Question1: what is selected indicators (input and output) to determine the level and position of industrial development of the provinces in demographic and educational dimensions?

The results obtained from performing four cycles of Delphi on selected variables of input and output were as the following table 1:

Table 1: confirmed variables

Inputs and outputs			
r	Output variables	Measurement unit	Symbol
1	Industrial outputs	Million Rials	Y1
2	Gross domestic product	Million Rials	Y2
3	Consumption of industrial intermediates	Million Rials	Y3
4	Energy consumed in industrial workshops with ten personnel and more	Million Rials	Y4
5	Number of employees in industrial workshops with ten personnel and more	Million Rials	Y5
6	Number of employees with higher education degrees in industrial workshops with ten personnel and more	Million Rials	Y6
i	**Input variables**		
1	Population	Person	X1
2	The training cost indifferent levels of education (school)	Million Rials	X2
3	The cost of research and higher education	Million Rials	X3
4	Higher education population	Person	X4

Question2: what is the mathematical model of dynamic data envelopment analysis using goal programming?

In the model, the objective function was in the form of minimizing adverse deviations of the GP model based on variations of units in different time periods. Model constraints were in the forms of goal constraints and rigid constraints. The model has been presented in a frictional form and is called Goal Programming Dynamic Data Envelopment Analysis (GPDDEA).

$$\min \sum_{t=1}^{T}\sum_{j=1}^{n}(d_j^{t+} + d_j^{t-})$$

s.t.:

$$\frac{\sum_{r=1}^{s} u_r^t y_{rj}^t \sum_{l=1}^{L} \rho_1^t K_{lj}^t}{\sum_{i=1}^{m} v_i^t x_{ij}^t \sum_{l=1}^{L} \beta_l^{t-1} K_{lj}^{t-1}} - d_j^{t+} + d_j^{t-} = 1, \quad j = 1, ..., n;\ t = 1, ..., T$$

$$\frac{\sum_{r=1}^{s} u_r^t y_{rj}^t \sum_{l=1}^{L} \rho_1^t K_{lj}^t}{\sum_{i=1}^{m} v_i^t x_{ij}^t \sum_{l=1}^{L} \beta_l^{t-1} K_{lj}^{t-1}} - d_j^{t+} + d_j^{t-} \leq 1, \quad t = 1, ..., T;\ j = 1, ..., n$$

$$u_r^t, v_i^t, \rho_1^t, \beta_l^{t-1} \geq \varepsilon > 0;\ d_j^{t+}, d_j^{t-} = 0;\ j = 1, ..., n;\ r = 1, ..., s;\ i = 1, ..., m;\ t = 1, ..., T;\ l = 1, ..., L$$

Model 1: GPDDEA

The parameters and variables of this model have been defined as follow:

u_r^t : The weight of r^{th} output during t period, v_i^t : weight of i^{th} input during t period, β_l^{t-1} : the weight of I^{th} semi-fixed input during $t-l$ period, ρ_1^t : weight of I^{th} semi-fixed input during t period which is considered as an output in this period, y_{r0}^t and x_{i0}^t are the values of r^{th} output and i^{th} input, respectively for unit j in time t, y_{rj}^t and x_{ij}^t are the values of r^{th} output and i^{th} input, respectively for j^{th} unit in time t, K_{lj}^t : I^{th} output of unit j during the period of $t+l$, d_j^{t+} : greater deviation of efficacy goal of j^{th} unit in time t, d_j^{t-} : the smaller deviation of efficacy goal of j^{th} unit in time t, S : the number of outputs, m : the number of inputs, L : the number of semi-fixed inputs, T : the number of time periods and n : the number of units. Model number 1 can receive inputs and outputs related to the time period of all units and make it possible to calculate relative efficiency of all units at different times only with one run. On the other hand, examining the model in further stages, it was found that the model differentiation has been improved compared to other presented models. These two cases are in line with knowledge acquisition of present study.

Question3: how is the relative efficiency of the provinces in term of industrial development from 2007 to 2016?

The relative efficiency of the provinces in term of industrial development in the mentioned period was calculated and the output of the model results in the GAMS software was placed in Excel Software as Table 2.

Question4: what is the rank of each province of the country in term of industrial development?

According to the average of the relative efficiency of the provinces from 2007 to 2016, the ranking of provinces was as Table 3.

According to the average of relative efficiency during 2007 to 2016, Khuzestan province was ranked first and Sistan and Baluchistan province ranked last. According to above table, it can be said that only eight provinces have a performance of above 0.5 and it should be tried to maintain and improve the industries in these provinces and more budget and industrial development should be allocated to the other provinces due to cheap labor cost in most of these provinces. Also, it would be better to find native strengths in these provinces to create an industrial development with proper efficiency based on these strengths.

Ranking of the country's provinces in different years is as the following table 4:

As it can be seen from Table 4, Bushehr and Khuzestan provinces have improved relative efficiency since 2011 due to their oil and gas industries. Therefore, the development of industries in the Iranian economy has become more dependent on oil and gas. It would be better to establish appropriate support to the proper operation of non-oil industries or select provinces with successes in non-oil industries and have a special role in the progress of these provinces by transferring the experiences to lower-efficient provinces. According to the table of the relative efficiency of provinces from 2007 to 2016, the diagram of the relative efficiency of provinces in 2007 was drawn as a diagram 1.

According to the table of the relative efficiency of provinces from 2007 to 2016, the diagram of the relative efficiency of provinces in 2016 was drawn as a diagram 2.

As it can be seen from Diagrams 1 and 2, Bushehr and Khuzestan provinces have improved relative efficiency since 2011 due to their oil and gas industries. Therefore, the development of industries in the Iranian economy has become more dependent on oil and gas. According to the table of the relative efficiency of provinces from 2007 to 2016, the diagram of the relative efficiency of provinces was drawn as a diagram 3.

6 Conclusion

What adds to the importance of this research is important from two perspectives: First, its performance is measured using a kind of data envelopment analysis model that simultaneously utilizes both the Goal Programming and dynamic planning patterns that have not been studied so far. It is also possible to differentiate between units and only one model can be used to calculate the efficiency of units at different times. Therefore, achieving this will open the door to math planning science and allow for more forward-looking evaluations for managers. Second: Obviously, this is a case pattern and cannot be used for the future, then the mathematical proof of this pattern and finding a proven pattern, which is a formula and a solution for any amount and data, has added to the importance of this research and creates a special distinction to other research achievements. It should be noted that considering the development of industries in all provinces of the country, the diversity of goals and aspirations as well as inputs and outputs for the model and the complexity of the real world in a quantitative evaluation is more fully introduced.

Since the research is done in the context of data envelopment analysis and many studies have been done on this technique, but in this study, with dynamic data, using Goal Programming, a new model is introduced in which the

Table 2: the relative efficiency of the provinces in term of industrial development from 2007 to 2016

Province /Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average of relative efficiency
Alborz	0.5199	0.5072	0.4480	0.4099	0.3581	0.2948	0.2676	0.2086	0.1950	0.1826	0.3392
Ardabil	0.2089	0.2722	0.2900	0.2690	0.2760	0.3134	0.3519	0.3976	0.4039	0.4077	0.3191
East Azarbaijan	0.4394	0.4832	0.4701	0.4356	0.4072	0.4087	0.4292	0.4084	0.3970	0.3852	0.4264
West Azarbaijan	0.2413	0.2563	0.2379	0.2442	0.2279	0.3064	0.3212	0.3443	0.3497	0.3529	0.2882
Bushehr	0.4703	0.6327	0.6171	0.5395	0.6782	0.9399	1.0000	1.0000	1.0000	1.0000	0.7878
Chahar Mahaal and Bakhtiari	0.1957	0.2645	0.2444	0.1947	0.2013	0.1249	0.2315	0.1765	0.1703	0.1643	0.1968
Fars	0.2761	0.3245	0.3144	0.2774	0.2878	0.3099	0.3272	0.4265	0.4304	0.4319	0.3406
Gilan	0.3542	0.4010	0.3916	0.3705	0.3532	0.3936	0.4096	0.4217	0.4197	0.4158	0.3931
Golestan	0.2273	0.2567	0.2458	0.2497	0.2474	0.3020	0.3085	0.3191	0.3194	0.3183	0.2794
Hamadan	0.2541	0.2878	0.2729	0.2812	0.2941	0.3239	0.3219	0.2816	0.2789	0.2752	0.2871
Hormozgan	0.2777	0.3544	0.3737	0.3348	0.3943	0.4666	0.5435	0.6020	0.6082	0.6110	0.4566
Ilam	0.3155	0.4699	0.4139	0.3785	0.4503	0.5171	0.3752	0.3336	0.3369	0.3383	0.3929
Isfahan	0.5947	0.6417	0.6016	0.5918	0.6209	0.6414	0.6405	0.6268	0.6090	0.5904	0.6159
Kerman	0.2936	0.3390	0.2910	0.2855	0.3165	0.3205	0.3724	0.4015	0.3984	0.3939	0.3412
Kermanshah	0.2484	0.2879	0.3026	0.3125	0.3298	0.3370	0.3570	0.3205	0.3210	0.3198	0.3136
North Khorasan	0.2422	0.2565	0.2818	0.2944	0.2897	0.2905	0.3245	0.1801	0.1751	0.1701	0.2505
Razavi Khorasan	0.4009	0.4413	0.4183	0.4174	0.3971	0.4117	0.3907	0.3695	0.3637	0.3570	0.3967
South Khorasan	0.2162	0.2514	0.2433	0.2242	0.2170	0.2273	0.2287	0.1680	0.1631	0.1583	0.2097
Khuzestan	0.7788	0.9257	0.8438	0.6756	0.7989	1.0000	0.8425	0.9194	0.9288	0.9329	0.8646
Kohgiluyeh and Boyer Ahmad	0.8932	0.8690	0.7447	0.5739	0.7390	0.8056	0.5262	0.5992	0.6054	0.6082	0.6964
Kurdistan	0.1855	0.2141	0.2052	0.2115	0.2262	0.2577	0.2713	0.3233	0.3338	0.3417	0.2570
Lorestan	0.2152	0.2233	0.2091	0.2013	0.2301	0.2475	0.2920	0.2612	0.2621	0.2616	0.2403
Markazi	1.0000	0.9988	0.8633	0.8506	0.8095	0.7850	0.8970	0.7743	0.7428	0.7116	0.8433
Mazandaran	0.3226	0.3961	0.3752	0.3548	0.3547	0.3592	0.3350	0.3938	0.3880	0.3811	0.3660
Qazvin	0.7533	1.0000	1.0000	1.0000	1.0000	0.7885	0.7862	0.6676	0.6291	0.5926	0.8217
Qom	0.4339	0.4557	0.4100	0.4279	0.4211	0.4187	0.4213	0.3899	0.3791	0.3680	0.4126
Semnan	0.7455	0.8802	0.7208	0.6290	0.5021	0.4901	0.4278	0.2766	0.2567	0.2391	0.5168
Sistan and Baluchestan	0.1001	0.1080	0.1029	0.1104	0.1393	0.1618	0.1755	0.1669	0.1686	0.1695	0.1403
Tehran	0.4217	0.4341	0.4103	0.3938	0.3678	0.3780	0.3711	0.2744	0.2641	0.2544	0.3570
Yazd	0.6350	0.6987	0.5989	0.5605	0.6012	0.6075	0.7057	0.6754	0.6501	0.6246	0.6358
Zanjan	0.4897	0.5199	0.4776	0.4672	0.4701	0.4410	0.4463	0.3955	0.3799	0.3645	0.4452

differentiation is improved and with solving only one model, the relative efficiency of all units can be calculated over a different time period. Meanwhile, in addition to this, a function is proposed to examine and predict the relative efficiency of industrial development in the provinces. These two new ideas will have effective capabilities for mathematics in management. On the other hand, the calculation of the relative efficiency of industrial development in the provinces of the country is carried out for the first time at the national level.

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Table 3: A ranking of Iran's provinces based on relative efficiency from 2007 to 2016

Rank	Province /Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average of relative Efficiency
1	Khuzestan	0.7788	0.9257	0.8438	0.6756	0.7989	1.0000	0.8425	0.9194	0.9288	0.9329	0.8646
2	Markazi	1.0000	0.9988	0.8633	0.8506	0.8095	0.7850	0.8970	0.7743	0.7428	0.7116	0.8433
3	Qazvin	0.7533	1.0000	1.0000	1.0000	1.0000	0.7885	0.7862	0.6676	0.6291	0.5926	0.8217
4	Bushehr	0.4703	0.6327	0.6171	0.5395	0.6782	0.9399	1.0000	1.0000	1.0000	1.0000	0.7878
5	Kohgiluyeh and Boyer Ahmad	0.8932	0.8690	0.7447	0.5739	0.7390	0.8056	0.5262	0.5992	0.6054	0.6082	0.6964
6	Yazd	0.6350	0.6987	0.5989	0.5605	0.6012	0.6075	0.7057	0.6754	0.6501	0.6246	0.6358
7	Isfahan	0.5947	0.6417	0.6016	0.5918	0.6209	0.6414	0.6405	0.6268	0.6090	0.5904	0.6159
8	Semnan	0.7455	0.8802	0.7208	0.6290	0.5021	0.4901	0.4278	0.2766	0.2567	0.2391	0.5168
9	Hormozgan	0.2777	0.3544	0.3737	0.3348	0.3943	0.4666	0.5435	0.6020	0.6082	0.6110	0.4566
10	Zanjan	0.4897	0.5199	0.4776	0.4672	0.4701	0.4410	0.4463	0.3955	0.3799	0.3645	0.4452
11	East Azarbaijan	0.4394	0.4832	0.4701	0.4356	0.4072	0.4087	0.4292	0.4084	0.3970	0.3852	0.4264
12	Qom	0.4339	0.4557	0.4100	0.4279	0.4211	0.4187	0.4213	0.3899	0.3791	0.3680	0.4126
13	Razavi Khorasan	0.4009	0.4413	0.4183	0.4174	0.3971	0.4117	0.3907	0.3695	0.3637	0.3570	0.3967
14	Gilan	0.3542	0.4010	0.3916	0.3705	0.3532	0.3936	0.4096	0.4217	0.4197	0.4158	0.3931
15	Ilam	0.3155	0.4699	0.4139	0.3785	0.4503	0.5171	0.3752	0.3336	0.3369	0.3383	0.3929
16	Mazandaran	0.3226	0.3961	0.3752	0.3548	0.3547	0.3592	0.3350	0.3938	0.3880	0.3811	0.3660
17	Tehran	0.4217	0.4341	0.4103	0.3938	0.3678	0.3780	0.3711	0.2744	0.2641	0.2544	0.3570
18	Kerman	0.2936	0.3390	0.2910	0.2855	0.3165	0.3205	0.3724	0.4015	0.3984	0.3939	0.3412
19	Fars	0.2761	0.3245	0.3144	0.2774	0.2878	0.3099	0.3272	0.4265	0.4304	0.4319	0.3406
20	Alborz	0.5199	0.5072	0.4480	0.4099	0.3581	0.2948	0.2676	0.2086	0.1950	0.1826	0.3392
21	Ardabil	0.2089	0.2722	0.2900	0.2690	0.2760	0.3134	0.3519	0.3976	0.4039	0.4077	0.3191
22	Kermanshah	0.2484	0.2879	0.3026	0.3125	0.3298	0.3370	0.3570	0.3205	0.3210	0.3198	0.3136
23	West Azarbaijan	0.2413	0.2563	0.2379	0.2442	0.2279	0.3064	0.3212	0.3443	0.3497	0.3529	0.2882
24	Hamadan	0.2541	0.2878	0.2729	0.2812	0.2941	0.3239	0.3219	0.2816	0.2789	0.2752	0.2871
25	Golestan	0.2273	0.2567	0.2458	0.2497	0.2474	0.3020	0.3085	0.3191	0.3194	0.3183	0.2794
26	Kurdistan	0.1855	0.2141	0.2052	0.2115	0.2262	0.2577	0.2713	0.3233	0.3338	0.3417	0.2570
27	North Khorasan	0.2422	0.2565	0.2818	0.2944	0.2897	0.2905	0.3245	0.1801	0.1751	0.1701	0.2505
28	Lorestan	0.2152	0.2233	0.2091	0.2013	0.2301	0.2475	0.2920	0.2612	0.2621	0.2616	0.2403
29	South Khorasan	0.2162	0.2514	0.2433	0.2242	0.2170	0.2273	0.2287	0.1680	0.1631	0.1583	0.2097
30	Chahar Mahaal and Bakhtiari	0.1957	0.2645	0.2444	0.1947	0.2013	0.1249	0.2315	0.1765	0.1703	0.1643	0.1968
31	Sistan and Baluchestan	0.1001	0.1080	0.1029	0.1104	0.1393	0.1618	0.1755	0.1669	0.1686	0.1695	0.1403

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Table 4: A ranking of Iran's provinces from 2007 to 2016

Rank	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	Markazi	Qazvin	Qazvin	Qazvin	Qazvin	Khuzestan	Bushehr	Bushehr	Bushehr	Bushehr
2	Kohgiluyeh and Boyer Ahmad	Markazi	Markazi	Markazi	Markazi	Bushehr	Markazi	Khuzestan	Khuzestan	Khuzestan
3	Khuzestan	Khuzestan	Khuzestan	Khuzestan	Khuzestan	Kohgiluyeh and Boyer Ahmad	Khuzestan	Markazi	Markazi	Markazi
4	Qazvin	Semnan	Kohgiluyeh and Boyer Ahmad	Semnan	Kohgiluyeh and Boyer Ahmad	Qazvin	Qazvin	Yazd	Yazd	Yazd
5	Semnan	Kohgiluyeh and Boyer Ahmad	Semnan	Isfahan	Bushehr	Markazi	Yazd	Qazvin	Qazvin	Hormozgan
6	Yazd	Yazd	Bushehr	Kohgiluyeh and Boyer Ahmad	Isfahan	Isfahan	Isfahan	Isfahan	Isfahan	Kohgiluyeh and Boyer Ahmad
7	Isfahan	Isfahan	Isfahan	Yazd	Yazd	Yazd	Hormozgan	Hormozgan	Hormozgan	Qazvin
8	Alborz	Bushehr	Yazd	Bushehr	Semnan	Ilam	Kohgiluyeh and Boyer Ahmad	Kohgiluyeh and Boyer Ahmad	Kohgiluyeh and Boyer Ahmad	Isfahan
9	Zanjan	Zanjan	Zanjan	Zanjan	Zanjan	Semnan	Zanjan	Fars	Fars	Fars
10	Bushehr	Alborz	East Azarbaijan	East Azarbaijan	Ilam	Hormozgan	East Azarbaijan	Gilan	Gilan	Gilan
11	East Azarbaijan	East Azarbaijan	Alborz	Qom	Qom	Zanjan	Semnan	East Azarbaijan	Ardabil	Ardabil
12	Qom	Ilam	Razavi Khorasan	Razavi Khorasan	East Azarbaijan	Qom	Qom	Kerman	Kerman	Kerman
13	Tehran	Qom	Ilam	Alborz	Razavi Khorasan	Razavi Khorasan	Gilan	Ardabil	East Azarbaijan	East Azarbaijan
14	Razavi Khorasan	Razavi Khorasan	Tehran	Tehran	Hormozgan	East Azarbaijan	Razavi Khorasan	Zanjan	Mazandaran	Mazandaran
15	Gilan	Tehran	Qom	Ilam	Tehran	Gilan	Ilam	Mazandaran	Zanjan	Qom
16	Mazandaran	Gilan	Gilan	Gilan	Alborz	Tehran	Kerman	Qom	Qom	Zanjan
17	Ilam	Mazandaran	Mazandaran	Mazandaran	Mazandaran	Mazandaran	Tehran	Razavi Khorasan	Razavi Khorasan	Razavi Khorasan
18	Kerman	Hormozgan	Hormozgan	Hormozgan	Gilan	Kermanshah	Kermanshah	West Azarbaijan	West Azarbaijan	West Azarbaijan
19	Hormozgan	Kerman	Fars	Kermanshah	Kermanshah	Hamadan	Ardabil	Ilam	Ilam	Kurdistan
20	Fars	Fars	Kermanshah	North Khorasan	Kerman	Kerman	Mazandaran	Kurdistan	Kurdistan	Ilam
21	Hamadan	Kermanshah	Kerman	Kerman	Hamadan	Ardabil	Fars	Kermanshah	Kermanshah	Kermanshah
22	Kermanshah	Hamadan	Ardabil	Hamadan	North Khorasan	Fars	North Khorasan	Golestan	Golestan	Golestan
23	North Khorasan	Ardabil	North Khorasan	Fars	Fars	West Azarbaijan	Hamadan	Hamadan	Hamadan	Hamadan
24	West Azarbaijan	Chahar Mahaal and Bakhtiari	Hamadan	Ardabil	Ardabil	Golestan	West Azarbaijan	Semnan	Tehran	Lorestan
25	Golestan	Golestan	Golestan	Golestan	Golestan	Alborz	Golestan	Tehran	Lorestan	Tehran
26	South Khorasan	North Khorasan	Chahar Mahaal and Bakhtiari	West Azarbaijan	Lorestan	North Khorasan	Lorestan	Lorestan	Semnan	Semnan
27	Lorestan	West Azarbaijan	South Khorasan	South Khorasan	West Azarbaijan	Kurdistan	Kurdistan	Alborz	Alborz	Alborz
28	Ardabil	South Khorasan	West Azarbaijan	Kurdistan	Kurdistan	Lorestan	Alborz	North Khorasan	North Khorasan	North Khorasan
29	Chahar Mahaal and Bakhtiari	Lorestan	Lorestan	Lorestan	South Khorasan	South Khorasan	Chahar Mahaal and Bakhtiari	Chahar Mahaal and Bakhtiari	Chahar Mahaal and Bakhtiari	Sistan and Baluchestan
30	Kurdistan	Kurdistan	Kurdistan	Chahar Mahaal and Bakhtiari	Chahar Mahaal and Bakhtiari	Sistan and Baluchestan	South Khorasan	South Khorasan	Sistan and Baluchestan	Chahar Mahaal and Bakhtiari
31	Sistan and Baluchestan	Sistan and Baluchestan	Sistan and Baluchestan	Sistan and Baluchestan	Sistan and Baluchestan	Chahar Mahaal and Bakhtiari	Sistan and Baluchestan	Sistan and Baluchestan	South Khorasan	South Khorasan

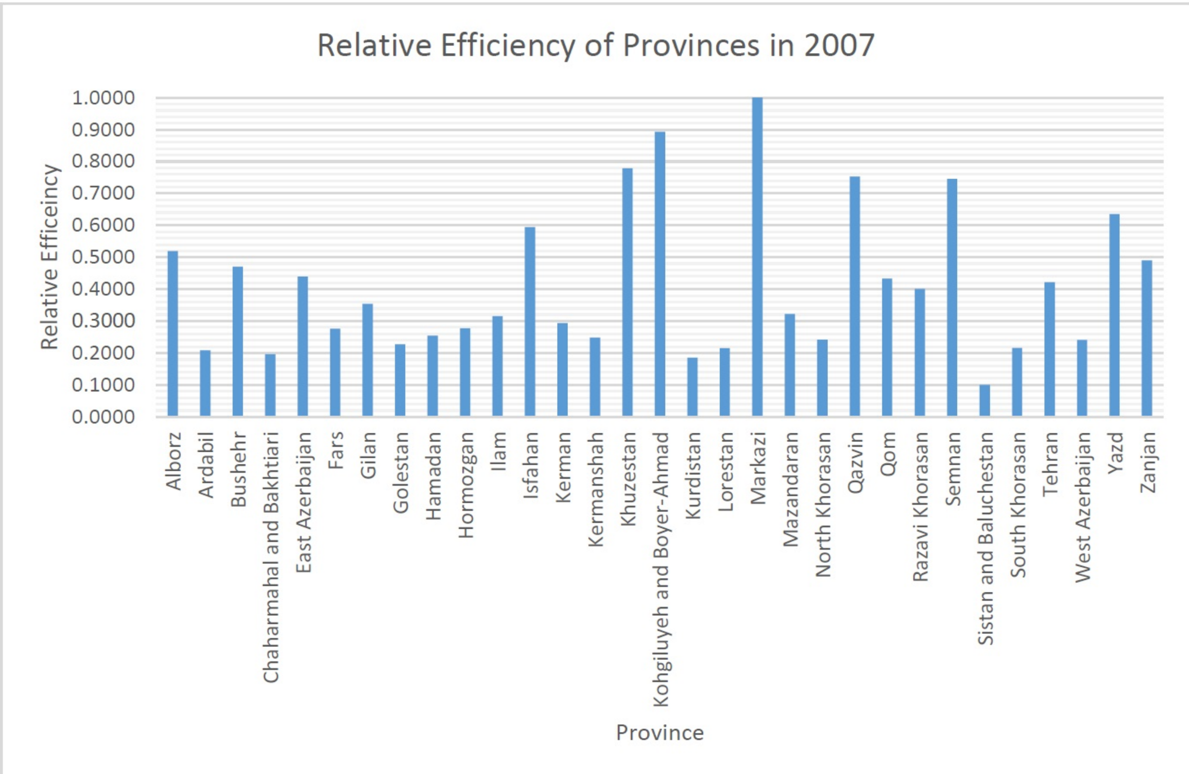

Figure 1: the relative efficiency of provinces in 2007

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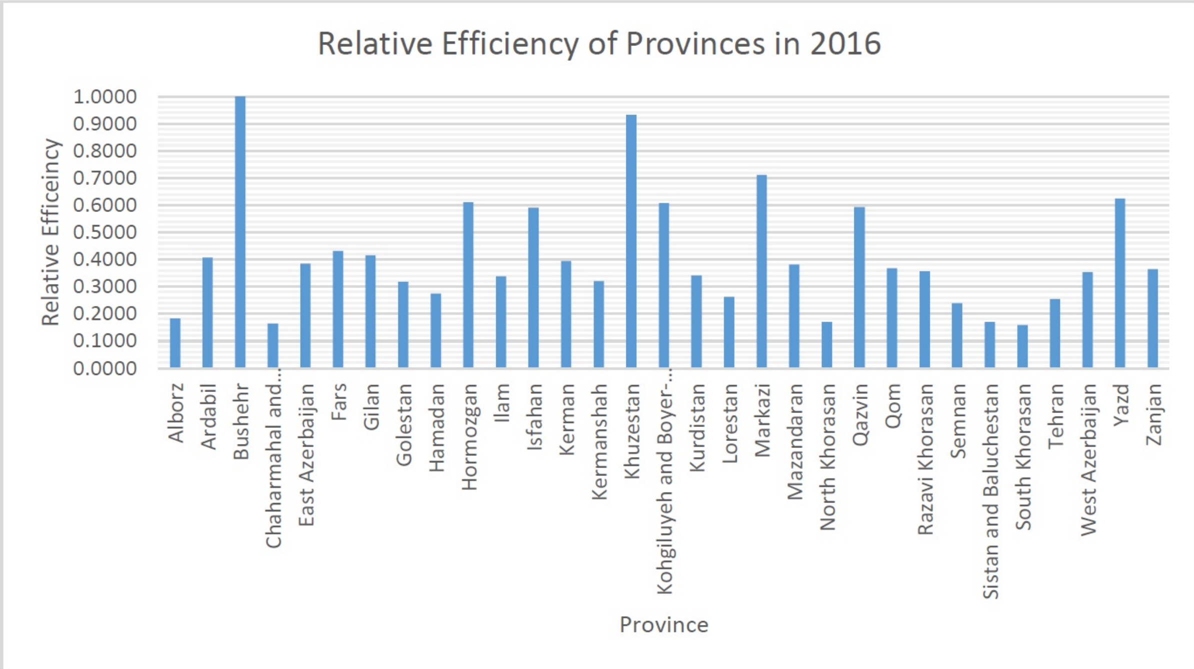

Figure 2: the relative efficiency of provinces in 2016

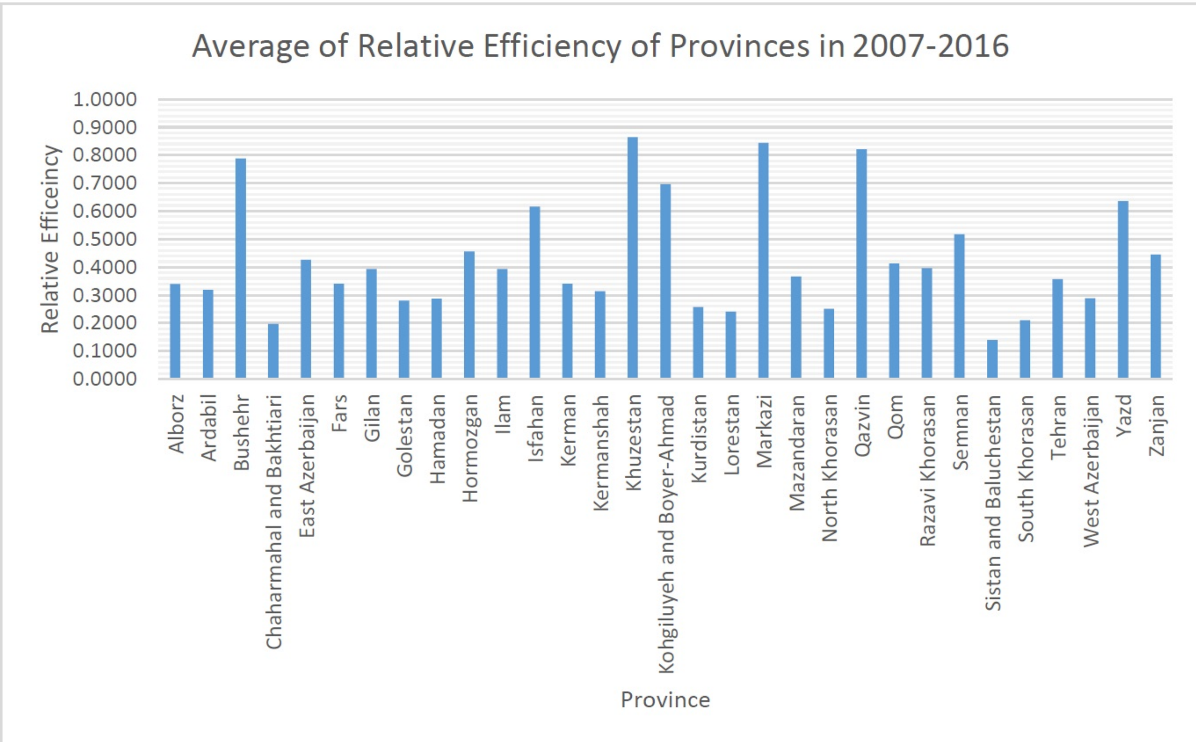

Figure 3: a diagram of the relative efficiency of provinces

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