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Evaluating the productivity using Malmquist index based on double frontiers data

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Abstract

The cement industry, as a basic industry, has an essential function in the development of a country's infrastructure. This industry in Iran, however, despite numerous advantages such as high-quality mines and the use of energy at an affordable price, faces many challenges. Problems such as misuse of the production capacity in the industry threaten productivity, making it an urgent need to conduct research into this area. Generally speaking, the Malmquist productivity index can help to compare a variety of companies in the industry and to formulate a benchmark to help companies progress in this area. This research used the Malmquist index based on double frontiers data in order to provide in-depth information about the productivity of 20 companies in the Iranian cement industry. Results showed that a concomitant consideration of double frontiers, or in other words a consideration of both optimistic and pessimistic views, yielded more accurate data than those of the traditional Malmquist index, which took into account only optimistic views in calculations.

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Keywords: productivity; Malmquist index; double frontiers;

1. Introduction

Productivity, as a strategy-regulated approach to performance improvement, represents one of the major goals of firms, setting the foundations for economic growth. Productivity involves using and effectively integrating the

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existing resources in a given company, as a necessary stage in the growth and development of the company, and can lead to an internalization of improvement in diverse (sub)systems of the company. In fact, one of the criteria for a company's improvement is its productivity measures. Therefore, productivity refers to an optimal use of a company's resources in order to achieve effective and efficient goals, within the framework of an agreed-upon value system (Díaz-Chao et al., 2015).

Due to the concerns mentioned above, advanced or developing countries regard productivity as a necessity for economic development and an opportunity for obtaining competitive advantage. Productivity, as well as the strategies fostering it, has also been a topical concern in Iran, especially as it is taken into account in the country's development plans.

In any case, considering the notion of productivity and making optimal use of resources can enhance the capacity of the companies involved. This same concern justifies the importance of the present research, which deals with the question how to make it possible to increase productivity improvement in the companies involved in the cement industry. To answer this fundamental question, the relative productivity of 20 companies providing services in the Iranian cement industry is investigated to yield a foundation for improving the current conditions in the industry under study.

Broadly speaking, to measure productivity, various methods can be used. These methods are divided into parametric and non-parametric approaches. Parametric methods, in their assumptions, rely on a preexisting function, whereas non-parametric methods do not need to assume the existence of a function and create a function based on empirical observation. One of the most recent non-parametric methods that measures a company's performance from the perspective of financial and non-financial dimensions is the Malmquist index (MI).

The MI is conducted based on data envelopment analysis (DEA) and can measure productivity changes over time, presenting the shifts in terms of efficiency change (EC) and technical change (TC). Furthermore, the MI can analyze TC based on scale efficiency change and input-mix change. Taking account of the dimension of time and conducting multidimensional (non)finical analyses have helped to increase the accuracy of the method compared to others (Ahn & Min, 2014).

As the review shows, however, many researches have only considered positivistic views; that is, their calculations only report the efficient frontier. In contrast, measures of pessimistic views can reveal their specific patterns. In fact, the results from these two sets of views are neither equal to nor interchangeable with each other. If each of the sets is used separately, part of possibly important information can be lost in in-depth analyses (Wang & Lan, 2011).

As a result, to overcome this problem and to enhance the accuracy of this study, the Malmquist index based on double frontiers is employed. In other words, this research seeks to implement the two optimistic and pessimistic views concurrently.

2. Review of the literature

Productivity and efficiency are two highly important notions in the evaluation of organizations' performance. Efficiency refers to the patterns of use and gaining benefit from facilities, such as natural, financial, and capital resources. From an economic viewpoint, efficiency is the relationship between input and output, or otherwise between the efforts made and the return gained. Measuring efficiency in today's world is not easy, because besides economic approaches, one has to pay attention to social and environmental factors as well. On this account, to evaluate efficiency, one has to use methods that allow for a concomitant evaluation of multiple criteria (Woo et al., 2015).

Considering the definitions in the literature, it can be clarified that the most important factor that is (implicitly) present in all of these definitions is the ratio between what is spent on production and what is gained as a result of production. Given the shortage of resources for production, the notion of productivity improvement, which is basically concerned with loss reduction, was conceptually expanded. The idea of productivity as "more output using less input" became a topical notion, which was introduced within "resource productivity".

Yet, as economy in most countries started to become more competitive, the conceptual aspects of productivity were expanded as well. Currently, productivity has moved beyond its former mono-dimensional state and is a concern for various institutions, such as small-scale financial institutions (Wijesiri & Meoli, 2015). As mentioned earlier, there are different methods for measuring efficiency and productivity, although DEA and Malmquist index, which compute efficiency and productivity respectively, provide certain advantages.

Although there are many methods proposed for measuring productivity, a comparison of all methods shows that DEA provides a better way of sorting and analyzing data. This method allows for productivity changes over time, while it does not require any assumption regarding productivity measurement (Wang et al., 2014). DEA is, in fact, a mathematic planning model used for the evaluation of decision making units' (DMU) productivity. This method uses several inputs and outputs to compare the productivity of relatively similar DMUs, such as schools, industrial organizations, or airports. In this method, the efficient frontier curve is decided through a series of points that are designed via linear programing.

The DEA of traditional data is regulated by the efficient frontier, which determines the best efficiency grade that can be assigned to a DMU. Because of this style of analysis, this method is called "optimistic". However, calculations can be conducted using the inefficient frontier too. In such a case, the worst relative efficiency grade can be assigned to a DMU (Azizi et al., 2013).

The Malmquist index, as mentioned earlier, is one of the most widely used methods that can trace productivity changes over a period of time. This index was first introduced by Malmquist in 1953 in the context of consumer theory and was extended to serve more purposes as it was further divided into two sub-sections: efficiency changes (EC) and technical changes (TC) (Zhang et al., 2015). The Malmquist index has been used to evaluate the productivity of many companies, as it computes the productivity changes of a given DMU over two periods of time (Woo et al., 2015).

The index is calculated through multiplying EC by TC, while it provides several advantages compared with other indices, such as the Fishers index. The first advantage of the Malmquist index is that requires a limited number of inputs and outputs for its calculations, without the need for implementing many modifications. Secondly, it does not require the evaluator to make an attempt to maximize the outputs or minimize the inputs. Additionally, it does not rely on fixed weights for the inputs and outputs (Grifell-Tatjé & Lovell, 1996).

These advantages can explain why this index has been frequently used in related researches. The productivity of the cement industry, too, due to its multifarious aspects of significance, has been scrutinized in numerous studies, which relied on the MI. Ghulam and Jaffry (2015) utilized the MI to study productivity in cement companies in Pakistan. Their findings revealed that privatization and lower degrees of governmental intervention in such companies, which was a development achieved through advanced technology levels, had a positive impact on the companies' productivity. Apparently, this improvement was associated with the stability of political conditions, the enhancement of the economic status, and an increase in competitiveness.

Long et al. (2015) compared the total productivity index with thr environmentally friendly productivity index. In addition, they used the MI to compare the productivity of the companies active in the industry. As the findings suggested, use of modern technology could help to correct the existing shortcomings. Zhang et al. (2015), employing the MI, evaluated the performance of activities including Co2 in the transportation industry in China. The investigation took place in several time periods, revealing that the performance of the Chinese transportation industry had declined by 32.8%. This reduction of performance was attributed to a low level of technology in the field.

As the review of the literature suggests, due to the particular nature of the cement industry, measuring the productivity in the industry is crucial and of course challenging. As shown above, the MI has already been used as a method for measuring productivity in the cement industry, while it has proven to be a practical method in this context. It should, of course, be noted that the MI, just like DEA, can yield richer data, if it considers both the efficient and inefficient frontiers. Yet, because a study that considers both of the frontiers has not been practiced either operationally or methodologically in Iranian researches, the present research sought to utilize the MI based on double frontiers in Iran's cement industry.

3. Methodology

Because the present research sought to evaluate the productivity of companies providing services in the Iranian cement industry, the research was of an applied and developmental type. The general goals of the research were to describe the current situation in the companies under study, from the perspective of productivity, and to propose strategies for productivity improvement in the industry in question. Given the fact that the study proposed a mathematic model based on the MI, the research followed a quasi-experimental operational design. More specifically, the research was conducted in an actual environment, while the researchers made every attempt to control the conditions of the dependent variables.

In this study, to obtain raw data, the information from 20 cement companies' balance sheets was collected, within 2012-13. After the calculations were conducted, the inputs and outputs were identified. The number of employees, tangible/intangible fixed assets, debt ratio, debt to net worth ratio were considered as the inputs, whereas current ratio, quick ratio, and net profit/loss margin were counted as the outputs. To identify the number of employees, the companies' documents were referred to. To determine the values for the second input variable, the values of tangible/intangible fixed assets were used.

To compute the third output variable (net profit/loss margin), net sales were divided by profit/loss. The indices used in this research, were relied on in prior research to measure productivity in the cement industry and were found to be effective. On this account, from the existing indices, these particular ones were selected to yield an accurate estimate of the productivity of the companies under study. Other studies, such as those conducted by Pourjam (2008) and Mostafa and Dashti (2009), emphasized the importance of these specific indices.

Models 1-4 below were used to determine the MI, with a view to the efficient frontier (see Wang and Lan, 2011):

(1)
$$\begin{aligned} & D_O^t\left(x_O^t, y_O^t\right) = \min\theta \\ & st: \\ & \sum_{j=1}^{n} \lambda_j x_{ij}^t \le \theta x_{io}^t \qquad i = 1,2,...,m \\ & \sum_{j=1}^{n} \lambda_j y_{ij}^t \ge \theta y_{ro}^t \qquad r = 1,2,...,s \\ & \lambda_j \ge 0 \qquad j = 1,2,...,n \end{aligned}$$

(2)
$$\begin{aligned} & D_O^t\left(x_O^{t+1}, y_O^{t+1}\right) = \min\theta \\ & st: \\ & \sum_{j=1}^{n} \lambda_j x_{ij}^t \le \theta x_{io}^{t+1} \qquad i = 1,2,...,m \\ & \sum_{j=1}^{n} \lambda_j y_{ij}^t \ge \theta y_{ro}^{t+1} \qquad r = 1,2,...,s \\ & \lambda_j \ge 0 \qquad j = 1,2,...,n \end{aligned}$$

(3)
$$\begin{aligned} & D_O^{t+1}\left(x_O^{t+1}, y_O^{t+1}\right) = \min\theta \\ & st: \\ & \sum_{j=1}^{n} \lambda_j x_{ij}^{t+1} \le \theta x_{io}^{t+1} \qquad i = 1,2,...,m \\ & \sum_{j=1}^{n} \lambda_j y_{ij}^{t+1} \ge \theta y_{ro}^{t+1} \qquad r = 1,2,...,s \\ & \lambda_j \ge 0 \qquad j = 1,2,...,n \end{aligned}$$

(4)
$$\begin{aligned} & D_O^{t+1}\left(x_O^t, y_O^t\right) = \min\theta \\ & st: \\ & \sum_{j=1}^{n} \lambda_j x_{ij}^{t+1} \le \theta x_{io}^t \qquad i = 1,2,...,m \\ & \sum_{j=1}^{n} \lambda_j y_{ij}^{t+1} \ge \theta y_{ro}^t \qquad r = 1,2,...,s \\ & \lambda_j \ge 0 \qquad j = 1,2,...,n \end{aligned}$$

Models 1-4 showed optimistic efficiency changes (OEC), whereas models 2-3 represented optimistic technical changes (PTC) from time periods *t* to *t+1*. Based on models 1-4, the optimistic MI was calculated via:

(1)
$$MPI_O(Optimistic) = (OEC * PEC) = \frac{D_O^{t+1}\left(x_O^{t+1}, y_O^{t+1}\right)}{D_O^t\left(x_O^t, y_O^t\right)}\left[\frac{D_O^t\left(x_O^t, y_O^t\right)}{D_O^{t+1}\left(x_O^t, y_O^t\right)} * \frac{D_O^t\left(x_O^{t+1}, y_O^{t+1}\right)}{D_O^{t+1}\left(x_O^{t+1}, y_O^{t+1}\right)}\right]^{0.5}$$

The first element in relation 2 measured OEC, considering the following conditions:

- If the value was more than 1, optimistic efficiency took place over the improvement period;
- If the value was less than 1, optimistic efficiency dropped over the period;
- If the value was equal to 1, optimistic efficiency did not undergo any changes over the period.

Relation 1 also could be used for the inefficient frontier, as reflected by models 5-8 (Wang and Lan 2011):

(5)
$$\begin{aligned} & D_O^t\left(x_O^t, y_O^t\right) = \max\theta \\ & st: \\ & \sum_{j=1}^{n}\lambda_j x_{ij}^t \geq \theta x_{io}^t \qquad i = 1,2,\ldots,m \\ & \sum_{j=1}^{n}\lambda_j y_{ij}^t \leq \theta y_{ro}^t \qquad r = 1,2,\ldots,s \\ & \lambda_j \geq 0 \qquad j = 1,2,\ldots,n \end{aligned}$$

(6)
$$\begin{aligned} & D_O^t\left(x_O^{t+1}, y_O^{t+1}\right) = \max\theta \\ & st: \\ & \sum_{j=1}^{n}\lambda_j x_{ij}^t \geq \theta x_{io}^{t+1} \qquad i = 1,2,\ldots,m \\ & \sum_{j=1}^{n}\lambda_j y_{ij}^t \leq \theta y_{ro}^{t+1} \qquad r = 1,2,\ldots,s \\ & \lambda_j \geq 0 \qquad j = 1,2,\ldots,n \end{aligned}$$

(7)
$$\begin{aligned} & D_O^{t+1}\left(x_O^{t+1}, y_O^{t+1}\right) = \max\theta \\ & st: \\ & \sum_{j=1}^{n}\lambda_j x_{ij}^{t+1} \geq \theta x_{io}^{t+1} \qquad i = 1,2,\ldots,m \\ & \sum_{j=1}^{n}\lambda_j y_{ij}^{t+1} \leq \theta y_{ro}^{t+1} \qquad r = 1,2,\ldots,s \\ & \lambda_j \geq 0 \qquad j = 1,2,\ldots,n \end{aligned}$$

(8)
$$\begin{aligned} & D_O^{t+1}\left(x_O^t, y_O^t\right) = \max\theta \\ & st: \\ & \sum_{j=1}^{n}\lambda_j x_{ij}^{t+1} \geq \theta x_{io}^t \qquad i = 1,2,\ldots,m \\ & \sum_{j=1}^{n}\lambda_j y_{ij}^{t+1} \leq \theta y_{ro}^t \qquad r = 1,2,\ldots,s \\ & \lambda_j \geq 0 \qquad j = 1,2,\ldots,n \end{aligned}$$

Models 5-6 showed pessimistic efficiency change (PEC), whereas models 7-8 represented pessimistic technical change (PTC) from time period *t* to *t+1*. Based on these assumptions, the pessimistic MI was calculated via relation 2 (Wang and Lan, 2011).

(2)
$$MPI_O(Pessimistic) = \left(PEC * PTC\right) = \frac{D_O^{t+1}\left(x_O^{t+1}, y_O^{t+1}\right)}{D_O^t\left(x_O^t, y_O^t\right)}\left[\frac{D_O^t\left(x_O^t, y_O^t\right)}{D_O^{t+1}\left(x_O^t, y_O^t\right)} * \frac{D_O^t\left(x_O^{t+1}, y_O^{t+1}\right)}{D_O^{t+1}\left(x_O^{t+1}, y_O^{t+1}\right)}\right]^{0.5}$$

On this account, considering the efficient and inefficient frontiers, two values were assigned to the MI, and likewise two values were assigned to both EC and TC. The geometric mean was used to combine the two values. Relations 3-5 represent the MI, EC, and TC, respectively (see Wang and Lan, 2011).

(3) $$MPI_O = \left(MPI_O(Optimistic) * MPI_O(Pessimistic)\right)^{0.5}$$

(4) $$\text{Efficiency Change} = \left(\text{OEC} * \text{PEC}\right)^{0.5}$$

(5) $$\text{Technical Change} = \left(\text{OTC} * \text{PTC}\right)^{0.5}$$

4. Research findings

This research sought to evaluate productivity in the Iranian cement companies, employing the MI and double frontiers. Given the data collected, Table 1 shows the optimistic MI measured via models 1-4 (see above) for the 20 cement companies under investigation.

Table 1. Values of the Malmquist productivity index based on the optimistic approach

Co.	$D_O^t(x_O^t, y_O^t)$	$D_O^t(x_O^{t+1}, y_O^{t+1})$	$D_O^{t+1}(x_O^{t+1}, y_O^{t+1})$	$D_O^{t+1}(x_O^t, y_O^t)$	MPIo	OECo	OTCo
Urmia	0.384	0.628	0.565	0.356	1.610	1.472	1.094
Isfahan	1	0.836	0.951	1.207	0.811	0.951	0.854
Bojnourd	0.35	0.455	0.378	0.307	1.264	1.08	1.171
Behbahan	1	2.348	1	0.673	1.868	1	1.868
Khuzestan	0.325	0.612	0.440	0.241	1.857	1.355	1.371
Khazar	0.275	0.358	0.322	0.245	1.309	1.169	1.120
Dorud	0.196	0.219	0.198	0.183	1.097	1.009	1.088
Gharb	0.531	0.893	0.497	0.375	1.492	0.936	1.595
Neyriz White	1	1.331	1	1.123	1.089	1	1.089
Ilam	0.294	0.602	0.45	0.228	2.012	1.53	1.315
Darab	1	1.194	0.777	0.74	1.12	0.777	1.442
Shahrud	0.455	0.671	0.435	0.334	1.386	0.956	1.449
North	1	1.175	0.853	0.819	1.106	0.853	1.297
Sufian	1	0.267	0.224	1.013	0.243	0.224	1.086
Fars-Nov	1	1.721	0.929	0.679	1.535	0.929	1.652
Mazandaran	0.696	2.093	1	0.627	2.19	1.437	1.524
Qayen	1	0.822	0.887	1.362	0.731	0.887	0.825
Karoon	0.556	0.511	0.392	0.466	0.879	0.704	1.248
Lar/Sabzevar	0.24	0.237	0.161	0.168	0.975	0.672	1.45
Khash	0.391	0.56	0.464	0.316	1.451	1.187	1.222

In the light of the observed values in Table 1, it was clarified that, optimistically considered, Mazandaran Cement Co. showed maximum productivity among the companies under study. Of course, it must be stated that among the 20 companies, 15 ones experienced productivity improvement and only 5 ones showed productivity reduction in the period under investigation. Sufian Co. showed the highest rate of reduction in productivity. Yet, although Mazandaran Co. revealed maximum improvement growth, it did not necessarily experience maximum EC and TC improvement.

As can be observed, the highest efficiency improvement was reached by Ilam Co., whereas the highest technical improvement was achieved by Behbahan Co. Meanwhile, the highest rate of efficiency decline was seen in Sufian Co., whereas the highest rate of technical decline was found in Qayen Co.

Following the calculation of models 5-8, these changes could also been approached from a pessimistic perceptive. Table 3 represents these calculations. Thus, pessimistically considered, Khash Co. experienced the highest rate of productivity improvement. Maximum efficiency improvement was also achieved by Khash Co., while Neyriz White Co. showed the highest rate of technical improvement. From this perspective, 13 companies underwent a drop of productivity. Darab Co. experienced the highest degree of productivity and efficiency decline, whereas Dorud Co. showed maximum technical cutback.

As can be clearly seen, the results obtained from the optimistic and pessimistic analyses were not equal. As a result, to reach richer results, evaluations must consider double frontiers. Table 3 shows the final indices based on double frontiers.

Table 2. Values of the Malmquist productivity index based on the pessimistic approach

Co.	$D_O^t(x_O^t, y_O^t)$	$D_O^t(x_O^{t+1}, y_O^{t+1})$	$D_O^{t+1}(x_O^{t+1}, y_O^{t+1})$	$D_O^{t+1}(x_O^t, y_O^t)$	MPIo	PECo	OTCo
Urmia	1. 104	1.296	2.189	1.647	1.249	1.984	1.379
Isfahan	4.286	3.997	3.353	3.589	0.933	0.782	4.001
Bojnourd	1.412	1.665	1.99	1.75	1.16	1.412	1.637
Behbahan	4.121	5.223	5.754	4.472	1.277	1.391	5.263
Khuzestan	1	1.673	1.995	1.219	1.655	1.995	1.655
Khazar	1.092	1.397	1.92	1.56	1.254	1.758	1.37
Dorud	1	0.236	1	0.825	0.535	1	0.535
Gharb	1.265	2.392	2.74	1.579	1.812	2.167	2.291
Neyriz White	5.044	6.307	8.266	6.744	1.238	1.639	6.244
Ilam	1	1.908	2.433	1.305	1.886	2.433	1.886
Darab	2.819	3.64	0.225	3.185	0.302	0.08	0.852
Shahrud	1.617	1.918	2.41	0.946	1.212	1.491	1.96
North	3.516	2.903	2.683	3.518	0.793	0.763	2.79
Sufian	1	0.433	1	0.651	0.815	1	0.815
Fars-Nov	3.088	4.506	5.414	3.85	1.433	1.754	4.423
Mazandaran	1.978	2.782	3.324	3.103	1.228	1.68	2.428
Qayen	4.023	2.677	3.689	5.018	0.699	0.917	2.814
Karoon	1.212	1.198	1.357	1.346	0.988	1.12	1.21
Lar4Sabzevar	1	0.46	1	0.292	1.257	1	1.257
Khash	1.213	2.398	3.247	1.706	1.940	2.676	2.354

Table 3. Values of the Malmquist productivity index based on the double frontiers

Co.	MPI	TC	EC	Co.	MPI	TC	EC
Urmia	1.419	1.228	1.709	Darab	0.582	1.108	0.249
Isfahan	0.87	1.848	0.862	Shahrud	1.296	1.685	1.194
Bojnourd	1.211	1.385	0.235	North	0.937	1.902	0.807
Behbahan	1.545	3.136	1.182	Sufian	0.445	0.941	0.473
Khuzestan	1.753	1.506	0.644	Fars-Nov	1.483	2.703	1.276
Khazar	1.281	1.239	1.433	Mazandaran	1.64	1.924	1.554
Dorud	0.766	0.763	1.004	Qayen	0.715	1.524	0.902
Gharb	1.644	1.912	1.424	Karoon	0.937	1.229	0.888
Neyriz White	1.161	2.607	1.28	Lar4Sabzevar	1.107	1.35	0.82
Ilam	1.948	1.575	1.929	Khash	1.678	1.696	1.783

In the light of the data in Table 2, it was clarified that a combination of optimistic and pessimistic approaches could yield estimates different from the individual result of each of the approaches. This difference emphasized the importance of taking into account double frontiers. The combined results revealed that Ilam Co. experienced maximum growth in terms of productivity and efficiency. Meanwhile, Ilam Co. ranked second for productivity improvement, viewed both from the optimistic and pessimistic perspectives. As far as efficiency was concerned, Ilam Co. ranked first from the optimistic perspective, while it ranked second from the pessimistic perspective.

Behbahan Co. topped the list of TC, based on the double frontiers. Optimistically concerned, this same company had the highest rank, although pessimistically concerned, it ranked second. Sufian Co. showed maximum drop in productivity, whereas Dorud Co. experienced maximum technical decline. Finally, Darab Co. showed maximum decline in efficiency. Based on the investigations, Behbahan Co. implemented productivity management cycle at its production processes level (Iranian Center for Productivity Management, 2015), utilizing modern facets, such as management for organizational excellence, for improving its conditions.

In 2009 and 2010, Behbahan Co. obtained the Commitment to Excellence License from the secretariat of the Iranian Excellence & Productivity Award organization (Behbahan Cement Co., 2015). Obviously, this company well familiar with notions of productivity and performance. This familiarity could explain why the company achieved the highest rank among the cement companies under study. For the same reason, other companies providing services are recommended to consider productivity cycle and the tools for improving it, making it possible to obtain excellence in their performance.

5. Conclusion

Given the socio-economic growth and increasing significance of companies, evaluating the performance of companies and their management have been among topical concerns, while diverse indices have been proposed as criteria from firms' performance. The productivity index represents one of the existing indices used for firms' performance evaluation. Considering this fact, this study relies on the MI, as an effective instrument for evaluating the productivity of DMUs that share similar inputs and outputs.

As the results revealed, the results of optimistic and pessimistic approaches differed. As a result, to enhance the validly or reasrch projects, researchers must take into account double frontiers, incorporating both the optimistic and pessimistic frontiers. Results suggested that Ilam Cement Co. experienced maximum growth in productivity and efficiency over the time period under study. Behbahan Co., too, showed maximum improvement in terms of technical change. Other companies can gain experience from the strategies adopted by these two companies, implementing necessary modifications for the purpose of achieving improvement in their activities.

To extend the strategies observed in this study, the following suggestions can inspire related future researches: In many systems, one or multiple system outputs, contrary to the norm, are nor favorable and the system does not intend to advance them. For instance, transportations systems can lead to air pollution, which brings about adverse consequences. Thus, researchers have tries to deal with this type of output through the use of DEA or MI. Yet, although various methods have been proposed, there does not seem to be a consensus among researchers in this regard (Wang et al., 2014). Future studies can focus on unfavorable outputs, as an extension of DEA or MI methods.

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