African Journal of Agricultural Research Vol. 6(7), pp. 1802-1806, 4 April, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.733
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Using DEA window analysis for performance evaluation of Iranian wood panels industry

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Accepted 26 October, 2010

Wood panel manufacturing is one of the important sectors in Iranian wood industry. The sector faces serious limitations in production technology and raw materials. So the performance of 10 firms of Iranian wood panels industry was evaluated. A DEA window analyses with a free oriented slack-based measure model (SBM) were performed based on financial data collected for the period of 5 years (2002 to 2006). The (firms) decision-making units were ranked based on average of efficiency scores and determination of the trends of their behaviors and stability of performances. The results of estimated efficiency score showed that all decision-making units (DMUs) in wood panel sector were stable (considering low standard deviation). But their trends and stability behaviors showed that almost half of decision-making units were positive. The difference of total range and the efficiency score average showed that many DMUs still were inefficient and reflect a fluctuation in efficiency score.

Key words: Data envelopment analysis, performance evaluation, windows analysis, wood panels industry.

INTRODUCTION

Wood panel manufacturing is one of the important sectors in Iranian wood industry. The sector faces serious limitations in production technology and raw materials. Considering the ever-increasing rate of Iranian population, wood panels are getting used more and more every year. Based on Azizi et al. (2009), the present industries of wood panels in Iran should increase the production by 2.76 times to maintain its relative position in wood panels market in 2012. Considering this situation, performance evaluation of firms in Iranian wood panel industry is important to shareholders, managers and inventors.

Several methods have been suggested to evaluate a firm's performance, including estimation of a firm cost function, total factor productivity of a firm, the establishment of a firm performance and efficiency model using multiple regression analysis. In recent years, DEA has recently been used for analysis of firm's performance. DEA has the advantage of consideration which can be given to multiple inputs and outputs, compared with traditional approaches. The DEA methodology, which was firstly proposed by Charnes et al. (1978) determines the efficiency for group of decision–making units (DMUs) when measured over a set of multiple input and output variables, DEA produces a single comprehensive measure of performance for each DMU. Many researchers have used this model to evaluate the wood industry in other country's different models of DEA, (Nyrud and Bergseng, 2002; Nyrud and Bergseng, 2003; Hailu and Veeman, 2003; Salehirad and Sowlati, 2005; Salehirad and Sowlati, 2007; Balteiro et al., 2006; Jajri and Ismail, 2006); however, it has not yet been used in Iran. Therefore, in the present study, a DEA model introduced by Tone (2001) was used with title of 'slacks-based measure of efficiency (SBM). In this model with n DMUs with the input and output matrices $X = (x_{ij}) \in R^{m\times n}$ and $Y = (y_{ij}) \in R^{s\times n}$ respectively. λ is a non-negative vector in R^n. The vectors $S^- \in R^m$ and $S^+ \in R^s$ indicate the input exceeds and output shortfall respectively. SBM model in fractional form is as follows (Tone, 2001):

$$Min \quad P = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} S_i^- / X_{io}}{1 + \frac{1}{S}\sum_{i=1}^{s} S_i^+ / Y_{io}} \qquad (1)$$

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$$Subject\ to \quad X_o = X\lambda + s^-$$
$$Y_o = Y\lambda - s^+$$
$$\lambda \geq 0, s^- \geq 0, s^+ \geq 0$$

The optimal solution for SBM will be generated $(p^*, \lambda^*, s^{-*}, s^{+*})$. A DMU ($x_o$, y_o) is SBM – efficient, if P* =1. This condition is equivalent to $s^{-*} = 0$ and $s^{+*} = 0$, with out any input excesses and output shortfalls. SBM is non-radial and deals with input /output slack directly. The efficiency values measured by SBM falls between 0 and 1 (" m" is the number of input and "s" is the number of output).

SBM as formulated above can be transformed into the program below by introducing a positive scalar variable t. Then (SBMt) transfers to following linear program with t, $s^-, s^+ \ and\ \Lambda$ (Cooper et al., 2007):

$$(LP)\ Min\ T = t - \frac{1}{m}\sum_{i=1}^{m} S_i^- / X_{io} \qquad (2)$$

$$Subject\ to \quad 1 = t + \frac{1}{S}\sum_{i=1}^{s} S_i^+ / Y_{io}$$
$$tx_0 = x\lambda + s^-$$
$$ty_0 = y\lambda - s^+$$

$$\Lambda \geq 0, s^- \geq 0, s^+ \geq 0, t > 0$$

Note that the choice T > 0 means that the transformation is reversible and we have an optimal solution of SBM defined by:

$$P^* = T^*, \lambda^* = \Lambda^* / t^*, s^{-*} = s^{-*} / t^*, s^{+*} = s^{+*} / t^*$$

Windows analysis initiated by Charnes et al. (1985) is a time-dependent version of DEA. The basic idea is with regard to each DMU as if it is a different DMU in each of the reporting data. Then each DMU shall not necessarily be compared with the whole data sets, but instead only with alternative subsets of panel data. The windows analysis is based on the assumption that what was feasible in the past will remain feasible forever, and that the treatment of time in windows analysis is more in the nature of an averaging over the periods of time covered by window. There is no theory which determines the justification for the choice of window size (Cullinane et al., 2004).The following formulas are proposed to analyze the characteristics of the windows analysis.

N = number of firms, K = number of periods, P= length of window ($p \leq k$), and W = number of windows (k-p+1), where w= k- p+1 are number of analysis for each firm and ((n) (p) (w)) will be number of "different" firms.

An alternate formula to derive the total number of DMUs is as follows: Total number of different DMUs: n (k-p+1) p.

The identification of performance trends in the row window and the stability are defined in columns. The variation in row reflects both the absolute performance of a DMU over time and the relative performance of that DMU in comparison to the other DMUs (Al- Eraqi et al., 2008).

The data used in this study were obtained from the annual financial reports of firms, by fax, e-mail, through internet and questionnaires. Two inputs and three outputs of financial variables were selected in five consequence years, 2002 to 2006, for evaluating performance efficiency in wood panels firms.

This study was carried out:

(1) To determine the convenient inputs and outputs to measure performance efficiency for each firm of wood panel sector.
(2) To rank firms based on average of efficiency score,
(3) To determine the trend and stability behavior of firms during five consequent years since 2002 to 2006.

MATERIALS AND METHODS

As needed common principles of filed studies, different variables were gathered for studying the subject. Primary variables, then, were selected through studying the references and interview with industrial experts and professionals. After that, preliminary screening, first questionnaire was prepared and sent to industry owners, directors, universities and their replies were collected. Final variables were extracted using averaging method. Questionnaires were collected and their figures revised in order to integrate and remove the inflation rate. External inputs and outputs measures were modulated and optimized on the basis of annual mean of wholesale cost index of Iranian central bank from 2002 to 2006. The free oriented SBM model was selected for and all the requirements of window analysis were employed. After determination of objective function and related restrictions and model running with lingo software, performance efficiency measurements of time periods for decision-making units were determined as a non-parametric figure ranging zero to one. Values of performance efficiencies then were studied through window analysis. Relative mean performance efficiency, standard deviations, maximum range changes in columns and total changes calculated and all decision–making units were ranked based on the achieved relative mean performance efficiency. Finally their trends and stability behaviors were determined. Wood panels firms were assigned the codes from "WPA" to "WPJ" listed in this research.

RESULTS

The sum of assets and the total costs as input variables and operational income, net profit and total seal as output variables are presented in Table 1 followed by the summary of variable characteristics in Table 2.

Table 1. Abbreviation of variable selected with Average method.

	Output variables		Input variables		
Average	0.89	0.70	0.86	0.82	0.73
Factor	1	2	1	2	3
	Total cost	Sum of assets	Operational income	Net profit	Total seal

Table 2. Descriptive statistics of inputs and outputs.

Net profit	Operational income	Total sale	Total costs	Sum of Assets	Parameters
33598075.4	35264423.9	216294659.1	160505202.1	1293053864.3	Mean
41088354.4	35319642.7	158018764.6	87251651.1	1088381151.7	Standard deviation
1305483.0	2101968.3	88772846.0	79373368.2	93994778.1	Minimum
180134680.1	201683501.7	1033348491.1	509427609.4	3134186818.0	Maximum

All numeric's of parameters is based on USD.

Table 3. Correlation coefficients with inputs and outputs.

Net profit	Operational income	Total sale	Total costs	Sum of assets	Variables
				1.000	Assets
			1.000	0.665(**)	Total costs
		1.000	0.911(**)	0.559(**)	Total sale
	1.000	0.690(**)	0.700(**)	0.660(**)	Operational income
1.000	.625(**)	0.597(**)	0.465(**)	.361(**)	Net profit

** Correlation is significant at the 0.01 level (2-tailed).

The final data of all decision-making units were collected after gathering the second questionnaires and the data and their changes were controlled according to the values of goods and wholesale indexes in Iranian central bank. After selecting inputs and outputs, Spearman correlation coefficient analyses were used to test whether they are isotonic. As shown in Table 3, the variables selected are positively correlated.

The free oriented slack-based measure model was applied to select the wood panel firms in terms of the variables. There after, DEA window was used to analyze the efficiency score of wood panels sector. The window analysis was used to examine the efficiency overtime for the period 2002 to 2006, K=5, P=3 and W=3. DEA was carried out on 10 wood panel firms. Thus there are 90 different data points which the DEA model were applied to obtain the efficiency scores exhibited. Tables 4 and 5 represent the efficiency estimates, the average of DEA efficiency scores, the standard deviation, the maximum ranges' change in columns and its total range in the columns denoted "Mean", "S.D" "M.C.Range" and "T.Range". As previously mentioned, no theory underpins the definition of window size. As such, the length of window used herein is defined as three. Three separate windows are represented as separate rows in Table 4. The rows can be used to examine trends that occur in each window, and the columns used to examine stability properties (Cooper et al., 2007).

Taking a firm with code of WPC, as an example, efficiency in the first window is 9.70, 11.90 and 14.90 in comparison to row average of 12.16 and total average of 21.55; these figures correspond to the estimated relative efficiency of WPC, for 2002Q1, 2003Q2 and 2004Q3; and clears that trend behavior in the first row is positive, but its amount is lower than total average. In the third window, relative efficiency estimates standing at 27.70, 28.70 and 33.60 correspond, respectively, to 2004Q3, 2005Q4 and 2006Q5 with row average of 30.00 and total average of 21.55; thus you would see that the trend behavior in the third row is positive, and its amount is higher than total average. This approach used in formulating Table 4, leads itself to study the trend and the examination of the stability of efficiency across and within the windows by adoption of row views and column views respectively based on total average score. Still taking the firm with the code of WPC, as an example, its efficiency varies from 9.70 in year 2002 to 33.60 during 2006 (adopting a row view perspective). At the same time, the

Table 4. Windows analysis matrices for DMUs of wood panel sector.

DMUs	2002 Q1	2003 Q2	2004 Q3	2005 Q4	2006 Q5	Average*	DMUs	2002 Q1	2003 Q2	2004 Q3	2005 Q4	2006 Q5	Average*
WPA	15.60	9.10	8.30			11.00	WPF	100.00	100.00	100.00			100.00
		13.80	13.50	13.50		13.60			100.00	100.00	50.80		83.60
			10.50	10.60	9.50	10.20				100.00	50.80	100.00	100.00
Average*	15.60	11.45	10.76	12.05	9.50	11.60	Average*	100.00	100.00	100.00	50.80	100.00	89.06
WPB	61.40	59.20	41.40			54.03	WPG	78.20	26.30	64.00			56.16
		85.30	64.70	100.00		83.33			29.40	64..60	20.70		38.23
			55.60	100.00	100.00	85.20				66.70	20.70	17.16	34.87
Average*	61.40	72.25	53.90	100.00	100.00	74.17	Average*	78.20	27.85	65.10	20.70	17.16	43.13
WPC	9.70	11.90	14.90			12.16	WPH	24.80	50.10	43.30			39.40
		11.20	23.80	24.50		19.83			53.30	26.70	18.50		32.83
			27.70	28.70	33.60	30.00				24.50	17.50	30.90	24.30
Average*	9.70	11.55	22.13	26.60	33.60	21.55	Average*	24.80	51.70	31.50	18.00	30.90	32.17
WPD	100.00	46.80	48.60			65.13	WPI	100.00	64.40	24.30			62.90
		68.10	70.90	69.40		69.46			66.30	55.30	100.00		73.86
			100.00	91.10	28.70	73.26				46.40	100.00	100.00	82.13
Average*	100.00	80.85	73.16	80.25	28.70	69.28	Average*	100.00	65.35	42.00	100.00	100.00	72.96
WPE	41.60	27.50	21.00			30.03	WPJ	27.10	25.30	68.30			40.23
		56.40	61.80	46.40		54.86			41.70	33.10	34.40		36.40
			58.90	42.00	43.40	48.10				28.40	30.50	29.60	29.50
Average*	41.60	41.95	47.23	44.20	43.40	44.33	Average*	27.10	33.50	43.26	32.45	29.60	35.37

(100 = "efficient").

efficiency of a DMU within the different windows can also vary substantially (adopting a column view perspective). This variation reflects simultaneously both the absolute performance of a decision-making unit over time and its relative performance in comparison to the others in the sample. So verification of trends behavior in row window and stability is defined in column of each year in comparison of total average score, and allows controlling both of them in separate windows. The efficiency score estimated shows that all firms in wood panel sector are stable (have low standard deviation). But their trends and stability behaviors show that almost half of firms are positive. The difference of total range and the efficiency score mean value shows that further DMUs are still inefficient and reflect a fluctuation in efficiency score. It should be mentioned that the efficiency results reported here are based on the financial data and are included in the DEA models. It means that the results show how efficient the firms are in using inputs to produce outputs.

DISCUSSION AND CONCLUSION

In this paper, DEA window analysis was used to determine the dynamic relative efficiency (performance) of Iranian wood panels sector. The panel data in the window analysis provided large details of performance analysis over a period of time.

The total range changes at firms showed that wood panel industry had high fluctuations. It had shown that 10 firms became efficient only16 times out of 90 times of model- running in the total years,

Table 5. Results of windows analysis for DMUs of wood panel sector.

DMU	Mean	S.D	M.C.Range	T.Range	Trend behavior	Stability	Ranking
WPF	89.06	21.69	0.00	49.20	+	+	1
WPB	74.17	22.41	26.10	58.60	+	+	2
WPI	72.96	28.34	22.10	75.70	+	+	3
WPD	69.28	24.86	51.40	71.30	-	-	4
WPE	44.33	13.86	40.80	40.80	+	-	5
WPG	43.13	24.52	3.10	60.60	-	-	6
WPJ	35.37	13.25	39.90	43.00	-	-	7
WPH	32.17	13.40	18.80	35.80	-	-	8
WPC	21.55	8.14	12.80	23.90	+	+	9
WPA	11.60	2.54	5.20	7.30	-	-	10

which was equal to 0.17 of total performances.

Some firms had shown lower standard deviation compared to others. For example, the firms with the code of "WPC" have been related to decrease in production and were stable at the lowest level of production. If these firms fail to improve their performance level they will be defeated in competition.

Many of 10 firms at this research were particle board producers which had obtained about 75% of total production capacity. So, the samples showed the position of the whole of Iranian wood panels industry. With average taking from each year (column), the performance efficiency from 2002 to 2006 changed from 55.84 to 49.29% and showed a partial decrease in the optimize production ability of wood panels industry.

Using the free oriented "SBM" model based on financial and real data, it was revealed that some of firms were not able to reach the balance in their inputs and outputs. In fact most of them should apply the strategies to decrease their inputs to obtain the same of outputs level (firms with code of "WPD", "WPE" and "WPG"). The others should decrease the inputs and increase the outputs simultaneously (" WPJ", "WPH", WPC" and "WPA").

The efficiency measurements revealed that although three firms in wood panel sector (WPF, WPB, and WPI) were in good condition due to negative behavior in trend and stability, other firms were in undesirable position. It seemed that due to the economic condition, short of raw material, destruction of the forests and lack of proper plantation, production and export limitations, wood-based panel industries were decreased their actual production capacities in comparison to their nominal capacities.

ACKNOWLEDGEMENTS

This article is extracted from PhD dissertation of Mr. Shademan Pourmousa (PhD student of Science and Research Branch, Islamic Azad University, Tehran), titled "The evaluation of dynamic efficiency for Iranian wood industries using DEA and Window Analysis". The authors would appreciate management of the wood panels firms, Securities and Exchange Organization of Iran for sending the financial data of firms.

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