Economic Affairs, Vol. **69**(03), pp. 1207-1213, September 2024
DOI: 10.46852/0424-2513.4.2024.3

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RESEARCH PAPER

Determinants of Firm-level Technical Efficiency in the Indian Yarn Industry: Insights from Data Envelopment Analysis and Panel Regression

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Received: 25-05-2024 **Revised:** 10-08-2024 **Accepted:** 28-08-2024

ABSTRACT

The present paper attempts to evaluate the performance of Indian Yarn Industry and so focuses primarily on estimation of efficiency scores for IYI using its firm level data. Also it determines the major encouraging factors of firm level efficiency of IYI. The originality of this study is that it considers the potential simultaneous link between many factors influencing efficiency. The result shows that majority of firms have a mean Technical Efficiency (TE) greater than the average mean. The average TE of all firms combined indicates that on average, IYI generates 77% of the maximum producible output. The results of determinants of TE reveals that Advertising intensity of previous period is found to have a non-linear i.e. inverted U-shaped relationship with TE whereas Firm size and Research and Development Intensity are positively related with TE. On the contrary, Net export intensity is found to have a linear and negative relationship with TE. The relation between Firm Age and TE is found to be linear and positive. The effect of dismantling of MFA has a negative and significant effect on TE compared to the MFA period for IYI. The analysis reveals that in order to promote firm level technical efficiency of IYI, any policy changes that will lead to increase in Firm Size, Research and Development and Advertisement should be emphasized.

HIGHLIGHTS

- The average TE of all firms combined indicates that on average, IYI generates 77% of the maximum producible output.
- The effect of dismantling of MFA has a negative and significant effect on TE compared to the MFA period for IYI.
- Firm size, Advertisement and Research and Development Intensity are positively related with TE.
- The analysis reveals that in order to promote firm level technical efficiency of IYI, any policy changes that will lead to increase in Firm Size, Research and Development and Advertisement should be emphasized.

Keywords: Technical efficiency, Simultaneity, Non-Linearity, Firm level data, Data Envelopment Analysis, Panel Regression, Indian Yarn Industry

Indian Textile industry plays a crucial role in the economic development of the nation. This industry contributed two percent to the country's GDP, and seven percent of the industry output in value terms. The share of textile, apparel and handicrafts in India's total exports was 11.4% in 2020-21 (Annual Report 2021-22, Ministry of Textiles, Government of India (GoI)). The success of Indian textiles is heavily dependent on yarn, among others, and it acts as a

How to cite this article: Maiti, S. and Chakraborty, C. (2024). Determinants of Firm-level Technical Efficiency in the Indian Yarn Industry: Insights from Data Envelopment Analysis and Panel Regression. *Econ. Aff.*, **69**(03): 1207-1213.

Source of Support: None; **Conflict of Interest:** None

barometer for evaluating the performance of the Indian textile industry.

Indian Yarn Industry (IYI) is the most modern and efficient in the world. India has the world's second-largest spinning capacity behind China, with 47 Million Spindles and 0.75 million open-end rotors. It produces 4700 million kgs of spun yarn, 3,400 of which is cotton. 73% of spun yarn is cotton (Annual Report 2021-22, Ministry of Textiles, GoI).

With the termination of the MFA in 2005, competition in Indian textiles has expanded by orders of magnitude. As a result, in order to compete effectively, a manufacturing unit must work efficiently and yarn sector is not an exception. This necessitates the performance of IYI to be evaluated and the primary focus of this article is on estimation of efficiency scores for IYI. Additionally, the performance of IYI is not at all consistent across firms since each firm has its unique features that influence the development and success of that firm. Therefore, one has to be aware of the efficiency scores in order to evaluate the performance of IYIs at the company level, as well as to determine which businesses are falling behind, and devise suitable policies for such firms. As a result, there are several compelling reasons to investigate the efficiency scores of IYIs employing its firm-level data.

LITERATURE REVIEW

Some studies focused on Indian Yarn Industry considering its different issues and dimensions. Dikshit, Basak & Vagrecha (2015) examined the impact of MFA abolition on exports of yarn, fabric, garments, and textiles and clothing from 2001-02 to 2011-12 and found that exports of textile intermediates (yarn and fabric) and textiles and clothing increased significantly. Maiti and Chakraborty (2020) examines the extent of Output Oriented technical efficiency (OTE) of Indian yarn sector using firm level panel data over the period 1991-92 to 2015-16 in a single-output, multi-input model employing Data Envelopment analysis approach. The result suggests that average OTE varies between 65-82% across these years.

The review of the literature suggests much scope remains in doing research on estimating the TE of yarn and also by employing Data Envelopment Analysis (DEA). Furthermore, studies pertaining to the calculation of TE of IYI utilising firm-level data are lacking in the literature. The current study attempts to address this gap by estimating output-oriented TE (OTE) of IYI using DEA technique and firm-level data. Along with measuring TE, it is also necessary to understand the factors encouraging TE of IYI.

Given this background, the **objectives** of the present paper is two fold: **First,** it attempts to estimate TE of IYI and **Secondly,** the major encouraging factors of TE are tried to be determined.

METHODOLOGY AND DATA SOURCE

Methodology

This article employs a two-stage methodology. In the first step, the OTE scores for the Indian Yarn Industry are evaluated using DEA. In the subsequent phase, the factors that influence TE are identified.

Determinants of Technical Efficiency (TE)

After calculating Technical Efficiency, to find out the determinants of OTE, panel regression has been carried out under a seemingly unrelated regression (SUR) framework where each regression was adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity is adopted. The variables considered as possible determinants of OTE are Firm Size (FS), Firm Age (FA), Research and Development Intensity (RDI), Advertising Intensity (ADV), and Net Export Intensity (NXI). Panel regression analysis is done.

Multi-Fibre Agreement (MFA) sets national export quotas for textiles from developing to developed nations. So, the relevant question is what happens to IYI's TE following MFA's dismantling? To answer this question, a time dummy, D is introduced taking value 1 from 2005 onwards (i.e. period of dismantling of MFA) and 0 for the years before 2005 (i.e. MFA period).

A recurring issue is the possibility of simultaneity between TE and FS and TE and RDI. In order to address this issue, a model including three equations with TE, FS, and RDI as dependent variables has been developed. The proposed model is estimated that illustrates the simultaneous link between the above three variables. While estimating

the model, several structural equations are tested and the model with the best results is selected.

The chosen model of technical efficiency considers separate equations for TE, FS, and RDI; TE equation (equation 5), FS equation (equation 6), and RDI equation (equation 7) which are presented below:

$$TE = f[FS, RDI, FA, NXI, ADV_{(t-1)}, ADV^2_{(t-1)}, D] \quad ...1$$

$$FS = f[TE, RDI, FA, ADV, TE^2, RDI^2] \quad ...2$$

$$RDI = f[TE, FS, NXI_{(t-1)}, \left(\frac{K}{L}\right), PR, \left(\frac{K}{L}\right)^2, PR^2] \quad ...3$$

The specified equation for (i) TE is nonlinear in $ADV_{(t-1)}$ (ii) FS is nonlinear in *TE* and *RDI* and (iii) RDI is nonlinear in (*K*/*L*) and *PR*.

Data Source

This study utilises the CMIE Prowess database from 1991 to 2020. During the sample period, firms are chosen for which complete data on inputs, outputs, and determining factors are accessible. In this way, a sample of 22 firms for IYI has been chosen.

The study envisions a single-output four-input production technology. Output is measured by the sum of sales value and change in stock [Deshmukh and Pyne (2013)], inputs considered are raw material expenses, power and fuel expenses, salary and wages and capital which is measured by net fixed asset [Ghose and Chakraborti (2013), Bhandari and Ray (2011), Bhandari and Maiti (2007)].

For finding out the factors influencing TE, data on Firm Age, Firm Size, Research and Development Intensity, Net Export Intensity, and Advertising Intensity, is used. Firm Size is obtained for each firm as the ratio of a firm's value of output in real terms to value of industry output in real terms. Firm Age is obtained for each firm of each sector by the difference between present year and establishment year of that firm. Research and Development expense per unit of output is taken as Research and Development Intensity. Present paper uses (export minus import) to find the net effect of exports over imports. Net Export Intensity is obtained by the ratio of Export minus import to sales. Advertising intensity is measured by the ratio of Advertising expense per unit of sales.

RESULTS OF ANALYSIS

Estimated Results of Technical Efficiency

Table 1 shows the findings of IYI's OTE and the distribution of firms based on their output-oriented mean TE. Table 1 suggests that 13.63 percent of the firms being studied are fully efficient, which means they are on the frontier with technical efficiency equal to one for the entire sample period (1991-2020), while the rest of the firms are not fully efficient. 22.73 percent of inefficient firms have a mean TE of less than 0.500, which means they produce less than 50 percent of their maximum output. The number of firms with a mean TE between 0.500 and 0.600, 0.600 and 0.700, and 0.700 and 0.800 is the same: 4.55 percent. 13.63 percent of firms have a mean TE between 0.800 and 0.900, and 36.36 percent of the firms produce 90 to 99 percent of their maximum output. According to Table 2, when all 22 sample firms are included, the average technical efficiency varies from 0.165 to 1, with a minimum score of 0.165 and a maximum score of 1. The grand mean of TE of the firms (GRM), or the average of mean TE of all enterprises over the study period, is 0.766, indicating that the IYI generates 76.6 percent of its maximum producible output on average. 36.36 percent of firms have mean TE below the grand mean, whereas 63.64 percent of firms have mean TE above the grand mean. Thus, the majority of firms have mean TEs that exceed the GRM.

Table 1: Distribution of firms based on Output -Oriented TE scores in IYI

Mean TE scores	Percentage of firms
Below 0.500	22.72
0.500-0.600	4.55
0.600-0.700	4.55
0.700-0.800	4.55
0.800-0.900	13.63
0.900-0.999	36.36
1	13.63

Source: *Compiled by the Author.*

Results of Determinants of Technical Efficiency

In this model, there are three equations namely Technical efficiency, Firm size and RDI. Table 3 shows the TE equation's findings. While other

Table 2: Output Oriented Technical Efficiency of IYI

Variable	Range of Mean TE	Grand Mean of TE (GRM)	Percentage of Firms below the GRM	Percentage of Firms above the GRM
TE	0.165-1	0.766	36.36	63.64

Source: *Compiled by the Author.*

Table 3: Estimated Results of Simultaneous Equation Model of IYI: The Case of Efficiency Equation, Firm Size Equation and Research and Development Intensity Equation

	Efficiency Equation	**Firm Size Equation**	**Research and Development Intensity Equation**
Explanatory Variable	**Coefficient**	**Coefficient**	**Coefficient**
C	0.522*** (6.527)	0.040*** (12.586)	0.376*** (29.540)
FS	5.090*** (26.900)		1.338*** (13.081)
RDI	0.231*** (26.272)	0.162*** (8.060)	
TE		-0.195*** (-18.650)	-0.566*** (-27.073)
FA	0.0002** (2.416)	0.0005*** (43.539)	
MEI			
NXI	-0.002*** (-19.108)		
PR			0.010*** (29.974)
K/L			0.0002*** (46.711)
$NXI_{(t-1)}$			0.007*** (48.945)
ADV		0.016*** (15.106)	
$ADV_{(t-1)}$	0.805*** (60.230)		
$MEI_{(t-1)}$			
TE^2		0.232*** (27.203)	
NXI^2			
RDI^2		-0.148*** (-33.357)	
K/L^2			-3.04E-08*** (-7.588)
PR^2			4.01E-05*** (9.198)
$ADV^2_{(t-1)}$	-0.658*** (-50.352)		
D	-0.042*** (-31.098)		
Marginal Effect of FS	5.090		1.338
Marginal Effect of RDI	0.231	0.156 (4.661*) ^	
Marginal Effect of FA	0.0002	0.0005	
Marginal Effect of MEI			
Marginal Effect of PR			0.010 (20.574***) ^
Marginal Effect of K/L			0.0002 (5.497*) ^
Marginal Effect of $NXI_{(t-1)}$			0.007
Marginal Effect of $MEI_{(t-1)}$			
Marginal Effect of TE		0.161 (20.433***) ^	-0.566
Marginal Effect of NXI	-0.002		
Marginal Effect of ADV		0.016	
Marginal Effect of $ADV_{(t-1)}$	0.728 (24.462***) ^		
Marginal Effect of D	-0.042		
Adjusted R-squared	0.912	0.871	0.905
F-statistic	813.805	618.802	748.135
Prob (F-statistic)	0	0	0

*** *Significant at 1% level, ** Significant at 5% level, *Significant at 10% level; t values in parenthesis; ^ Indicates the value of Chi-square.*

Source: *Authors' own calculation.*

variables such as Firm size, R&D intensity, Firm age and Net export intensity are all linearly linked to TE (i.e. Advertising intensity has an inverted U-shaped connection with TE), only Advertising intensity has an inverted U-shaped association with TE. The Wald test, shown in Table 3, was used to determine the statistical significance of the prior period's advertising intensity. Thus, the result suggests that TE increases with increase in ADV in the previous period, FS, RDI and FA but falls with increase in NXI. Previous period advertising intensity and TE have an inverted U-shape relation, after a certain threshold, TE may rise with an increase in advertising expenditures in the prior period. Consumers' goodwill and education are bolstered, and sales are increased as a result of increased advertising spending by firms; however, after a certain point, technical efficiency may decrease as a result of decreased customer satisfaction due to the perception that increased advertising signals a decline in quality. Table 3 shows that the advertising intensity of the previous period has a positive marginal influence on TE, indicating that the advertising intensity of the previous period has a positive net effect on TE. Due to scale economies, imperfections in the capital market, and market power, big firms may be substantially more efficient than small ones Barman and Anoop, 2023, TE is also shown to be favourably associated with the intensity of research and development.

Fundamentally, research and development include the quest for many innovative approaches and the development of knowledge that expedite product development. On the one hand, it develops new technologies, and on the other, it improves a company's capacity to use current technologies, therefore increasing TE. TE also rises when firm age increases. Older firms may have greater expertise, better access to capital, and a more streamlined buyer-supplier relationship, which may lead to a higher level of productivity. However, a negative correlation exists between Net export intensity and TE. This may suggest that imports may have a greater beneficial effect on TE promotion than export. While a firm imports higher-quality raw materials and equipment, it may also increase its manufacturing efficiency. Evidence also implies that the import of intermediate items is a key conduit for technology diffusion this may also have a positive effect on efficiency. The removal of MFA has a considerable detrimental impact on technical efficiency. Firm efficiency may diminish in the post-MFA era owing to firms' inability to meet competitive demands in terms of price and quantity from other nations, and as a result of this adverse position, firms are unable to gain economies of scale in production, and efficiency may collapse.

According to the findings of the Firm Size Equation, technical efficiency and RDI have nonlinear relationships with FS, i.e., U-shaped and inverted U-shaped relationships, respectively, but firm age and advertising intensity are linearly associated, as shown in Table 3. It also shows that the marginal impact of technical efficiency and RDI is positive, and the statistical significance of these variables has been tested using the Wald test, which is shown in Table 3. It is observed that technical efficiency has a nonlinear, U-shaped relationship with FS. This may be due to the fact that initially, with an increase in TE, FS may fall, possibly due to investments in advanced technology and better management, but after a certain threshold level, with an increase in efficiency, FS increases, possibly due to the firms' efficient use of inputs and production of more output, resulting in an increase in firm size. Table 3 reveals that the marginal impact of technical efficiency on FS is positive, indicating that the overall effect of technical efficiency on FS is positive. Between RDI and FS, there is a nonlinear relationship that looks like an inverted U. One reason could be that firms that do research and development can come up with better ways to do things or make better products with the same amount of input Sahu *et al.* (2022). So, firms that use better processes and technology may be able to make more and better products, which can lead to an increase in firm size. However, after a certain point, an increase in RDI can lead to a decrease in FS. This may be because allocating too many resources to R&D can reduce efficiency if firms don't get the benefits of R&D, which can also lead to a decrease in FS. The positive marginal effect shows that the overall effect of RDI on FS is positive. FA and FS, as well as Advertising intensity and FS, have a positive association. The positive association between FA and FS might be attributed to the fact that a business that has been in the market for a long time is capable of developing a flawless market strategy and customer trust, and

therefore generating more, which could lead to an increase in firm size. Also, firms that spend more on advertising are more likely to easily introduce a new product into the market, increase sales, fight market competition, improve consumer goodwill, and educate consumers, which may require firms to produce more to meet the extra demand created by advertising, and thus firm size may increase.

For the Research and Development Intensity equation, whose results are presented in Table 3, it can be concluded that the variables Capital-labour ratio and Profitability ratio have nonlinear relationship with RDI whereas Technical efficiency, Firm size and Net export intensity of previous period are linearly related. Capital-labour ratio has an inverted U shaped relationship with RDI. As the values of marginal effect of Capital-labour ratio and Profitability ratio are found to be positive as is revealed from Table 3, it implies that these variables have positive relationship with RDI and the statistical significance of these variables has been checked by performing Wald test which is represented in Table 3. K/L and RDI have an inverted U-shaped connection. Possibly, capital-intensive industries have a high potential to generate more profits due to their ability to generate mass production, high growth, and the use of high technology (Seenaiah and Rath, 2018, Maiti and Chakraborty, 2023), thereby raising RDI; however, after a certain threshold limit, the increase in K/L may decrease. RDI may be reduced as a result of over-mechanization and large investments in machinery. The net impact of K/L on RDI is also favourable, as seen by the positive marginal effect. Firms' profits are a key stimulant to and source of finance for R&D, which results in a steady supply of health-improving new goods. So, a boost in PR may enhance RDI since businesses have more excess funds on hand, which encourages research and development intensity. This result is like the findings of Tyagi *et al.* (2018). TE is found to have a negative relationship with RDI. The reason may be that if TE of the firms increases may be by investment for improvement in the ability of the workers, better management, adequate monitoring efforts, etc which may lead to more and more production, then firms may become reluctant to invest in R&D and so RDI may fall. Linear and positive relationship is found between FS and RDI. Possibly a larger firm can be able to exploit economies of scale which influence firms to increase Research and development Intensity. The preceding period's net export intensity is positively connected to the intensity of research and development. The rationale might be because an increase in net exports generates more profit from the overseas market, hence increasing RDI.

CONCLUSION AND POLICY SUGGESTIONS

Using DEA, the current study calculates IYI's OTE over the period 1991-2020. In addition, it identifies OTE's deciding variables. The originality of this study is that it considers the potential simultaneous link between many factors influencing OTE. The majority of firms have a mean TE that is greater than the grand mean. The average TE of all firms combined was 0.77 for IYI, indicating that on average, IYI generates 77% of the maximum producible output. The results of determinants of TE reveals that Advertising intensity of previous period is found to have an inverted U-shaped relationship with TE, Firm size and RDI are positively related with TE. Net export intensity is found to have a linear and negative relationship with TE. The relation between FA and TE is found to be linear and positive. The effect of dismantling of MFA has a negative and significant effect on Technical Efficiency compared to the MFA period for IYI. The analysis reveals that in order to promote technical efficiency, any policy changes that will lead to increase in Firm Size, Research and Development and Advertisement should be emphasized.

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