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Factors affecting Technical Efficiency of Indian Fabrics Industry: A Fresh Look Using Non-Parametric Method

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Abstract

The present paper aims to access the performance of the Indian Fabrics Industry (IFI) across firms through estimating its efficiency scores covering the period 1991 to 2015 considering Centre for Monitoring Indian Economy (CMIE) firm level data using Nonparametric Method of Data Envelopment Analysis (DEA). It also attempts to find out the factors affecting the efficiency scores of IFI by employing panel regression, which allows for the possibility of simultaneity among the regressors. The present paper uses two-stage methodologies. First, the OTE scores are estimated using DEA. Secondly, the factors influencing TE scores are found out. The result suggests that on average IFI produces 76% of the maximum producible output and that most of the firms' performance is above average. The relationship between Technical Efficiency (TE) and some variables is found to be nonlinear; the relation between advertising intensity of the previous period and TE is inverted U-shaped. Firm Size, Research and Development Intensity, Net Export Intensity and Marketing Intensity are positively related to TE. It is observed that the effect of dismantling the Multi-Fibre Agreement has a negative effect on Technical Efficiency. The paper recommends policy changes leading to increases in Firm Size, Research and Development Intensity, Net Export Intensity, Advertising Intensity and Marketing Intensity to promote TE of IFI.

Keywords: Indian Fabrics Industry, Technical Efficiency, Data Envelopment Analysis, Panel regression, Simultaneity, Nonlinearity

JEL Classifications: C14, L25, L67

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1. Introduction

Industry acts as an engine of economic growth for any country. The manufacturing sector plays a vital role in industrial growth. Steady industrial growth helps sustain economic development. Among the different manufacturing industries in the country, the Indian Textile industry (ITI) is one of the oldest. It has now emerged as the major source of low-cost, quality products in the global market. It is the second largest textile industry in the world after China [Confederation of Indian Textile Industry (CITI), Annual Report 2016)]. India's textile industry contributed seven percent of the industry's output (in value terms) and 15 percent of the country's export earnings (Annual Report 2017-18, Ministry of Textiles, Government of India).

Background information and importance of Fabric Industry

ITI is a complex industry covering several types of fibers, for example, cotton, silk, synthetic, and regenerated man-made fibers, i.e., wool, and jute. The processes of converting these fibers into yarns and fabrics are spinning and weaving. The spinning process produces yarn, and the weaving process produces fabrics (Rao ,1989; Bedi ,2003; Devaraja ,2011; IBEF). Yarn and Fabric are two textile intermediates (Dikshit, Basa, Vagrecha, 2015). Yarn is a long, uninterrupted length of interlocked fibers (cotton, silk, synthetic and regenerated man-made fibers, wool, and jute), produced by spinning, which is appropriately used in the manufacture of textiles, sewing, crocheting, knitting, embroidery, or rope making. Whereas fabric is produced by weaving together cotton, silk, synthetic and regenerated man-made fibers, wool, and jute, or other threads. Fabrics are used for making things such as clothes, curtains, and sheets.

India's fabric production grew significantly to an estimated 188.88 lakh meters in 2019-20. Approximately 70 percent of fabric production consisted of cotton or cotton blends. Most fabric production occurs in the decentralized sectors, with the power loom industry (3.12 Lakh No.) generating 60 percent of the total whereas the number of Exclusive Weaving Mills (Non-SSI) is 173(Annual Report 2017-18, Ministry of Textiles, Government of India).

India's textile sector is broadly categorized into 25 major commodities, namely, RMG cotton, including accessories: cotton fabrics, madeups etc., manmade staple fiber, carpet (excluding silk), handmade, etc. The top 10 exported commodities of Indian textiles account for about 95.35% of total textiles exports. During 2019-20 the exports of all principal commodities showed a negative growth rate except for cotton fabrics, madeups, etc. (0.33%) and other textile yarn, fabric, madeup articles (4.23%). A major decline of (-) 49.73% was seen in exports of raw cotton, including waste followed by cotton yarn (-29.14%) and manmade staple fiber (-11.87%) (Department of Commerce, Ministry of Commerce and Industry, Government of India).

The performance of Indian textiles depends largely on fabrics, among other sectors, and it serves as a barometer for assessing the performance of the Indian Textile Industry (ITI). International trade in the textile and clothing industries has long been directed by the Multi-Fibre Agreement (MFA), which fixed national quotas for the export of textiles from developing countries to developed countries. With the arrival of the World Trade Organization in 1995, MFA was supplanted by the Agreement on Textiles and Clothing (ATC), under which the phasing out of the quota restrictions progressively in four stages within a 10-year period (1995-2004) was agreed. These four stages are; 1995 to 1997 (Phase I), 1998 to 2001(Phase II), 2002 to 2004 (Phase III), and January 1, 2005 (Phase IV). Export quotas were removed for textiles and clothing for the four scheduled groups, viz., yarn, fabrics, madeups, and cloth or apparel, at 16 %, 17%, 18%, and 49%, respectively (Verma, 2000; Manoj and Muraleedharan, 2016). The dismantling of MFA quota regime is encouraging, with new investment flowing and several initiatives taken by the government. Thus, it is indispensable for a producing unit to operate efficiently to face increased competition.

Therefore, the present paper is concerned with the estimation of efficiency scores for the Indian fabrics industry (IFI). Also, the performance of IFI is not at all uniform across firms, as each firm has its own characteristics that influence the growth and performance of that firm. Thus, for accessing the performance of IFI at the firm level as well as to identify the firms that are lagging and for framing appropriate policies for them, one should have knowledge about the efficiency scores. Thus, there are good reasons to look at the efficiency scores of IFI using firm level data.

2. Literature review

There are some studies related to the efficiency of IFI. Among them, Kumar et. al (2012) estimated Technical Efficiency (TE) and scale efficiency of the Indian Weaving (Fabrics) Industry employing Data Envelopment Analysis (DEA) and showed that the overall mean TE is 0.78; the mean pure TE is 0.86; and the overall average scale efficiency is 0.91. In the same year, Bhandari and Ray (2011) also estimated the levels of TE employing DEA in the Indian textiles industry at the firm level and concluded that West Bengal performed at higher average levels of TE, private sector firms were more efficient and technologically superior to public sector firms, and there is a positive association between TE and firm size. Verma, Kumavat and Biswas (2015) concluded that average TE score increased from 0.90 to 0.96 and percentage of efficient firm increased from 50% to 70% in the period of 2012 and 2013. Goyal, Kaur and Aggarwal (2017) noted that overall, TE is 0.83 and 25.74 percent of firms are fully efficient, whereas average pure TE is 0.88 and 42.58 percent of firms are technically efficient, and the mean scale efficiency is 0.94. Later De and Ghose (2018) estimated TE and find out the determinants of TE. They noted that TE improved after the withdrawal of the multi-fiber-trade-agreement.

Some of the studies used SFPF methods to measure TE, Bhandari & Maiti (2007) was among them. They found that average TE varies between 68% to 84% and individual firm's TE varies with firm specific characteristics such as age and size. They also argued that private sector firms are relatively more efficient, whereas Manonmani (2013) showed that capital was the main input factor, the sum of the elasticities of the factors of production is 1.8419, and the average TE of this industry is 0.941. Kambhampati (2003) and Gopalan and Shanmugam (2009) investigated the effect of the complete phasing out of MFA in 2005 on the efficiency of Indian textile firms and concluded that the phasing out of MFA has a negative effect on efficiency.

The perusal of the literature on IFI suggests that there are very few studies which are related to efficiency, and they mostly used the Stochastic Frontier Approach (SFA) to estimate Technical Efficiency (TE). Thus, there is a dearth in the study related to the estimation of TE of fabrics employing Data Envelopment Analysis (DEA). Also, studies relating to estimation of the TE of IFI using firm-level data are deficient in the literature. The present work tries to fill this gap and estimates Output oriented TE of IFI employing DEA approach using firm level data. Along with the measurement of TE, it is also essential to explain the factors behind the variation in TE.

Given this background, the objectives of the present paper are: first**,** to estimate the TE of IFI; and second, to identify the major determining factors of TE.

The rest of the paper is organized as: Section 3 discusses methodology and data sources. In subsection 3.1, the data and variables of measurement are discussed. Subsection 3.2 presents methodology for calculating output-oriented technical efficiency and methodology for finding out determinants of output-oriented technical efficiency. Section 4 presents the results of analysis and Section 5 presents the summary and conclusion.

3. Data and methodology

This section discusses methodology and data sources. In subsection 3.1, the data and variables of measurement are discussed. Subsection 3.2 presents the methodology for calculating output-oriented technical efficiency and methodology of panel regression for finding out determinants of output-oriented technical efficiency.

3.1 Data and Variables measurement

The present paper uses Centre for Monitoring Indian Economy (CMIE) Prowess database from 1991 to 2015. Those firms are selected for which all the inputs, outputs, and determinants are available throughout the sample period. Based on this fact, a sample of 21 firms for IFI has been selected. The share of 21 firms in total output is 22%.

The study visualizes 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 assets (Ghose and Chakraborti, 2013; Bhandari and Ray, 2011; Bhandari and Maiti, 2007). All the data are in Rs. Millions, which are deflated by appropriate wholesale price indices (the base year being 2004-05) to obtain their real values. The value of sales and change in stock of the textile firms are deflated by the price index of textiles; power and fuel consumption by the price index for fuel, power and lubricants; expenditure on raw materials by the price index of material consumed; expenditure on salary and wages by the consumer price index for industrial workers; and expenditure on capital by the price index for machinery and equipment. Relevant price indices are collected from the Index Number of Wholesale Prices in India published by the Office of the Economic Advisor, Ministry of Industry, Government of India, Udyog Bhaban, New Delhi.

For finding out the factors influencing TE, data on Firm Size, Research and Development Intensity, Net Export Intensity, Advertising Intensity, and Marketing Intensity are used. Firm Size is obtained for each firm as the ratio of a firm's value of output in real terms to the value of industry output in real terms. Research and Development expense per unit of output is taken as Research and Development Intensity. Advertising Intensity is measured by the ratio of Advertising expenses per unit of sales. Marketing expense per unit of sales is taken as Marketing Intensity. In tune with Zhang, Ondrich, and Richardson (2004), the present paper uses (exports minus imports) to find the net effect of exports over imports. Net Export Intensity is obtained by the ratio of Export minus import to sales. Trend of output, employment, capital investment level and R&D is presented in Figure 1, Figure 2, Figure 3, and Figure 4, respectively.

3.2 Methodology

The present paper uses two stage methodologies. First, the OTE scores are estimated using DEA. Secondly, the factors influencing TE scores are found out.

3.2.1. Measurement of Output-oriented Technical Efficiency (OTE)

The TE of a firm can be measured either by 'output-oriented' or 'input-oriented' measure. The present thesis estimates OTE by DEA. In case of OTE, it can be calculated by comparing its actual output with the maximum producible output from its observed inputs, i.e., by how much the output quantities can be proportionally expanded without altering the input quantities used. In input-oriented TE, it can be calculated by comparing the actual input in use with the minimum input that would produce the targeted output level. To measure efficiency, one has to construct the production possibility set empirically from observed data. In parametric methods, one assumes an explicit specification of the production function (in the single output case) or the transformation function (in multiple output case) and uses suitable statistical methods to obtain estimates of the parameters from sample data. But in Data Envelopment Analysis, one makes some general assumptions regarding underlying technology, but there is no explicit functional form of the production function.

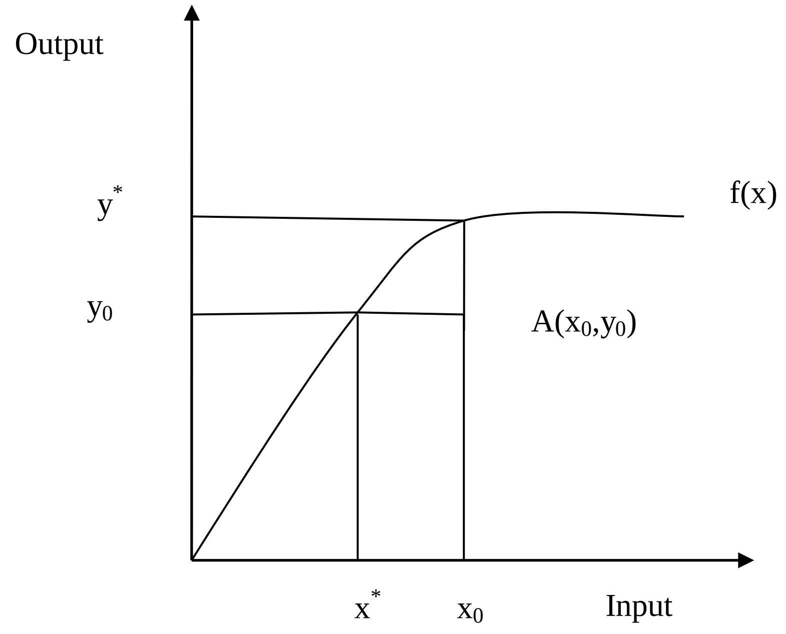
DEA is a linear programming problem which can provide a mean efficiency within a group of organizations. The efficiency of an organization is calculated relative to the group's observed best practices. Fried, Lovell, and Schmidt (1994) argued that DEA can provide appropriate role models to serve as possible benchmarks for a program of performance improvement and the most efficient production facilities. They also concluded that by using DEA one can get the optimum scale and optimum size of output if all inputs are performed according to best practice. So, by DEA one can easily identify those inputs which are not efficient and those outputs which are inefficient.

To measure efficiency, one has to empirically create the production possibility set from the observed data. In parametric methods, one assumes an explicit specification of the production function (in the single output case) or the transformation function (in the multiple output case) and uses suitable statistical methods to obtain estimates of the parameters from sample data. But in Data Envelopment Analysis, one makes some general assumptions regarding the underlying technology, but there is no explicit functional form of the production function. Introduced by Charnes, Cooper, and Rhodes (CCR) (1978) and afterward generalized by Banker, Charnes, and Cooper (BCC) (1984), DEA allows to empirically create the production possibility set from the observed data.

DEA was originally formulated by Charnes, Cooper, and Rhodes (CCR, 1978). The original CCR model was applicable only to technologies characterized by constant returns to scale (CRS) globally. Later Banker, Charnes, and Cooper (BCC) (1984) extended the CCR model to accommodate technologies that exhibit variable returns to scale (VRS).

In the case of single input and single output, both 'input-oriented' and 'output-oriented' measures of technical efficiency can be visualized in Figure 1.

Figure 1: The Input and Output Oriented Measure of Technical Efficiency



Source: Authors' own compilation

In Figure 1, input x is measured along the horizontal axis and output y along the vertical axis. Point A (x_0, y_0) represents the actual input-output bundle of firm A. Now $y^* = f(x_0)$ where y* is the maximum output that can be produced from input x_0.The output-oriented measure of TE for firm A is $\frac{y_0}{y^*}$ which is the comparison of actual output with maximum producible output from observed input. The input-oriented TE for firm A is $\frac{x^*}{x_0}$.

The technical efficiency score of a firm has a value between 0 and 1. A value of 1 indicates that the firm is fully technically efficient.

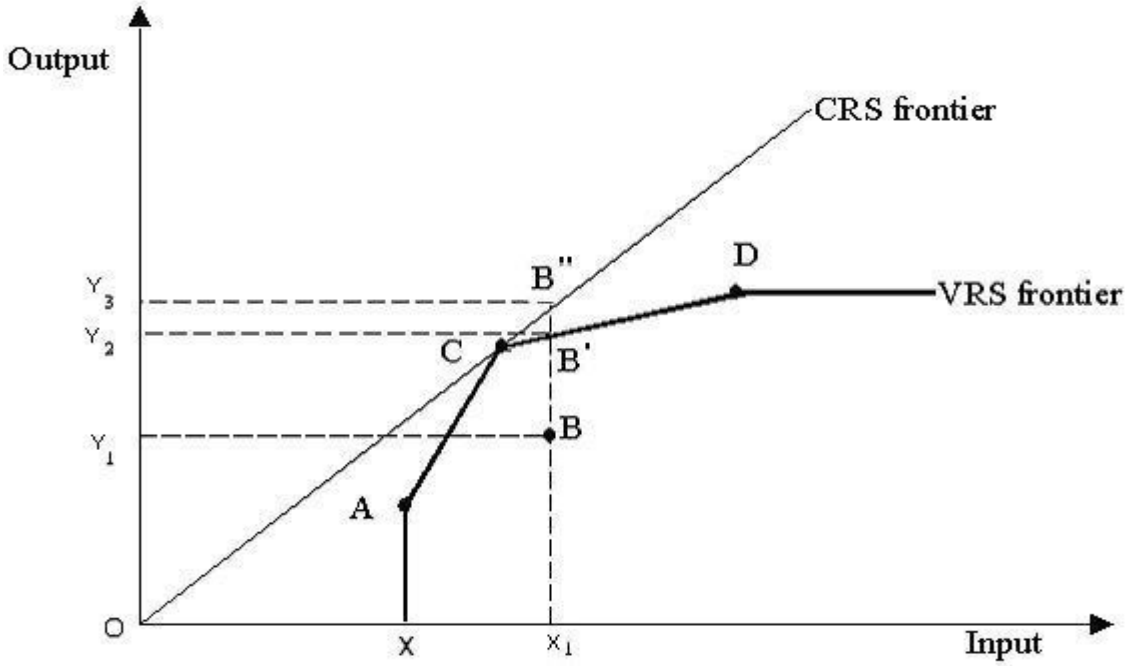
In the DEA, a benchmark technology is constructed from the observed input-output bundles of the firm in the sample without any assumptions regarding the production frontier. The general assumptions about the production technology are as follows:

- i) All observed input-output combinations are feasible.
- ii) The production possibility set is convex.
- iii) Inputs and outputs are freely disposable.

These are weak assumptions. These assumptions hold for all production technologies represented by quasi-concave and weak monotonic production functions.

Figure 2 illustrates the basic ideas behind DEA and returns to scale. Four data points such as A, B, C, and D are used here to describe the efficient frontier and the level of capacity utilization under the CRS and VRS assumptions. In a simple single output and single input DEA problem, points A, C, and D are found to be efficient, while point B is inefficient. So, unit B can produce more output at point B' on the frontier (which is equal to the theoretical maximum) by utilizing same level of input as at X_1. With CRS, the frontier is defined by point C for all points along the frontier, with all other points falling below the frontier (hence indicating capacity underutilization). With VRS, the frontier is defined by points A, C, and D, and only point B lies below the frontier, i.e., shows capacity underutilization. So, the capacity output corresponding to VRS is smaller than the capacity output corresponding to CRS.

Figure 2: The Production Frontier and Returns to Scale



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The present paper measures the technical efficiency of the textile companies assuming variable return to scale (VRS) using the nonparametric method of Data Envelopment Analysis (DEA) and rests on an output-oriented measure of TE.

It is supposed that there are N firms. Each of them is producing 'q' outputs using 'p' inputs. The firm s uses the input bundle $x^s = (x_{1s}, x_{2s}, \ldots x_{ps})$ and produces the output bundle $y^s = (y_{1s}, y_{2s}, \ldots y_{qs})$. Technology can either follow CRS or VRS.

The production possibility set corresponding to CRS can be defined as:

$$T^{CRS} = \{(x, y): x \geq \sum_{j=1}^{N} \lambda_j x^s; y \leq \sum_{j=1}^{N} \lambda_j y^s;\ \lambda_j \geq 0; (j = 1,2, \ldots \ldots N)\} \qquad (1)$$

The specific production possibility set corresponding to VRS can be defined as:

$$T^{VRS} = \{(x, y): x \geq \sum_{j=1}^{N} \lambda_j x^s; y \leq \sum_{j=1}^{N} \lambda_j y^s; \sum_{j=1}^{N} \lambda_j = 1;\ \lambda_j \geq 0, (j = 1,2, \ldots, N)\} (2)$$

The output-oriented measure of TE of firms under CRS technology requires the solution of the following LP problem:

max ϕ

subject to $\sum_{j=1}^{N} \lambda_j y_{rj} \geq \phi y_{rs}$; (r = 1,2, …, q);

$\sum_{j=1}^{N} \lambda_j x_{ij} \leq x_{is}$;(i=1, 2, …, p).

ϕ free; $\lambda_j \geq 0$; (j=1, 2, …, N) (3)

Output oriented TE of firms can be determined by using Equation (4).

$$TE_0^{cs} = TE_0^{cs}(x^s, y^s) = \frac{1}{\phi^*} \quad (4)$$

Where ϕ^* is the solution of Equation (3) showing the maximum value of ϕ . y* is the maximum output bundle producible from input bundle X^s and is defined as y*=$\phi^* y^s$.

Under VRS, maxϕ, ϕ^* ,can be determined by solving Equation (3) along with the constraint $\sum_{j=1}^{N} \lambda_j = 1$, considering the VRS frontier (Equation 2). Knowing ϕ^*, TE of the firm can be solved using similar methodology corresponding to CRS.

3.2.2 Determinants of Technical Efficiency (TE)

Following the calculation of OTE, panel regression was used to determine the determinants of OTE for IFI. The variables considered as possible determinants of TE are Firm Size (FS), Research and Development Intensity (RDI), Net Export Intensity (NXI), Advertising Intensity (ADV), and Marketing Intensity (MEI). The explanations for the inclusion of these variables can be justified as follows:

It is interesting to test whether Firm Size has any influence on promoting the TE of the firm or not. From the theoretical viewpoint, the relationship between firm size and efficiency is not clear (Audrestch, 1999). It can be hypothesized that large firms will be more efficient because of the presence of a threshold limit in production, scale economies, and imperfection in the capital market (Kumar, 2003). However, beyond a certain limit, higher market power may also plague the firm with X-inefficiency (Leibenstein, 1966), which may lead to lower efficiency. Bhandari and Ray (2011), Yasar and Paul (2009), Truett and Truett (2009), Tran, Graften and Kompas (2008), Bhandari and Maiti (2007), Cheng and Lo (2004), Mengistae (1998), Ramaswamy (1994) among others, investigated the link between firm size and the efficiency of the firm. Some of the studies found a positive relationship between the two, while others postulated a negative relationship. There exists a debate between firm age and efficiency in the existing literature due to Bhandari and Maiti (2007, 2011), Berghäll (2006), Walujadi (2004), Lundvall and Battese (2000), Stinchcombe (2000), Mengistae (1996, 1998), and Marshall (1920), among others. The role of Research and Development (R&D) may be significant when determining the factors explaining the TE of the Indian Textile Industry. R&D on the one hand generates new technologies, and on the other hand, it enhances a firm's ability to exploit existing technologies. Different studies in the international as well as Indian literature have considered Research and Development as the determinants of efficiency, at the aggregate country level, at sector level or at the firm level (Scannell et al. (2012); Kumbhakar et al. (2011); Mazumder et al. (2010); Yang et al. (2009); Ferrantino (1992), among others. Advertising may play a crucial role into explaining technical efficiency. Advertisement helps to introduce a new product in the market easily, increases sales, fights market competition, enhances goodwill with consumers, and educates them (Shashikanth, Mamatha &Rao ,2018; Samad & Sabeerdeen ,2016; Mohan,1989). Linkages between advertising intensity and technical efficiency for the Spanish manufacturing firms and Indian engineering goods industries, respectively, are due to Carod and Blasco (2005), and Goldar et al. (2004), whereas Ray (2006) did not find any impact of advertising on TE in the Indian manufacturing sector. Marketing intensity may serve as a proxy for product differentiation due to Pal, Chakraborty and Ghose (2018), Ghose and Chakraborti (2013), among others. Kao et al. (2006), Hurwitz and Caves (1988), Leffler (1981), among others, got positive relationship between marketing intensity and technical efficiency. Whereas Sheth and

Sisodia (2002) claimed that low efficiency is due to the sliding of marketing effectiveness.

The important aspect of IFI is that firms re-engineer the imported items and then re-export the product (De &Ghose, 2018). Thus, a related question may arise whether the efficiency of this industry is affected by trade-related variables or not. A vast amount of literature is available supporting the role of exports in promoting efficiency both at the theoretical as well as the empirical level (Grossman &Helpman, 1991; Balassa, 1993; Barro &Sala-i-Martin, 1995; Clerides et al., 1998; World Bank, 1993; Huallachain, 1984; Feder, 1983; Greenaway &Sapsford, 1994; Balassa, 1993; Chen & Tang, 1990; Kwon, 1986; Greenaway, 1986, Mok et al., 2010; Walujadi, 2004; Sun et al., 1999; Chen &Tang, 1987). Also, World Bank Report (1993, 1997) reported that firms' import of foreign technology has a positive impact on efficiency. Mazumder et al. (2010), and Goldar et al. (2004) reported a positive relationship between technical efficiency and imports in the Indian context. The above discussion reveals that both exports and imports may affect efficiency, so it may be interesting to determine the relative role of exports versus imports in fostering efficiency. In tune with Zhang, Ondric and Richardson (2004), the present paper uses net exports to identify the relative role of exports versus imports in influencing efficiency.

Global trade in the textile and clothing industries has long been governed by the Multi-Fibre Agreement (MFA), which set national quotas for the export of textiles from developing countries to developed countries. With the coming of the WTO in 1995, the MFA was replaced by the ATC, under which a 10-year (1995-2004) quota phasing out transitional period was agreed upon, i.e., to phase out the quota restrictions progressively in four stages, i.e., in the years 1995-1997 (Phase I), 1998-2001(Phase II), 2002-2004 (Phase III) and January 1, 2005 (Phase IV). Export quotas were removed for textiles and clothing for the four scheduled groups, viz., yarn, fabrics, made-ups, and cloth or apparels at 16 %, 17%, 18%, and 49%, respectively (Verma, 2000; Manoj and Muraleedharan, 2016). Thus, one may also be interested in knowing what happens to the TE of the firms of IFI after the dismantling of MFA. To answer this question, a policy 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).

The relation between FS and the explanatory variables can be justified as follows: A positive relation between TE and FS may occur because, with an increase in TE, the firm may produce more output, so there can be an increase in firm size. RDI may affect FS positively, possibly due to the fact that firms engaged in R&D can invent superior processes and technologies or produce better products employing the same level of input (Aghion &Howitt, 1992; Grossman &Helpman, 1991). Thus, firms may produce better and more products, thereby increasing their firm size. A positive relation may exist between Firm Age and Firm Size as well as Advertising Intensity and Firm Size. Perhaps a firm that stays in the market for a long period is capable of acquiring perfect market strategy and consumer faith and thus producing more, which may lead to a firm size increase. Also, firms spending more on marketing are more likely to introduce a new product into the market easily, which increases sales, and fights market competition, which may insist firms produce more to meet the extra demand created by marketing, thereby increasing firm size. An increase in sales in foreign markets may increase the firm's size, especially if net exports increase.

The relationship between RDI and the explanatory variables can be justified as follows: TE may affect RDI positively or negatively. A positive relationship may prevail between these two due to an increase in TE; the capability of firms through using their input efficiently may rise and produce more output which can promote research and development intensity. Also, there can be a possibility of a negative relationship, possibly due to several reasons such as improvement in the ability of the workers, better management decisions, adequate monitoring efforts, etc., which may lead to more and more production, thereby making firms more reluctant to invest in R&D and so RDI may fall. A positive relationship is expected between Firm size and RDI, which may be due to the fact that a larger firm can be better able to exploit economies of scale, which influence firms to increase RDI and further maintain economies of scale. A positive association between NXI and RDI may exist, possibly due to the fact that with an increase in net exports, the firm may generate extra profit from foreign markets and increase RDI. It is hypothesized that the higher the degree of mechanization in the production system, the higher the R&D expense of the firm. On the other hand, capital-labour ratio may negatively affect the firm's R&D expenses due to underutilization of capital. The Capital-labour Ratio (K/L) may be obtained for each sector by dividing capital by labour. A firm's profits are an important stimulus for, and source of funding for R&D, which in turn may lead to a positive relationship between profit and RDI. The Profitability Ratio (PR) is obtained for each sector by dividing the profit by the sales volume.

For determinant analysis, panel regression analysis is done under a seemingly unrelated regression (SUR) framework where each regression is adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity is adopted.

A common problem may be that simultaneity may exist between TE and FS and TE and RDI. Therefore, to take care of this problem, the model has been framed with three equations, considering TE, FS, and RDI as dependent variables. The proposed model is estimated in a panel setup showing simultaneous relationships among different variables. While estimating the model, various alternatives to the structural equations are tried out and a model with a better result is chosen. The chosen model of technical efficiency considers separate equations for TE, FS, and RDI; TE equation (Equation 7), FS equation (Equation 8), and RDI equation (Equation 9) which are presented below:

$$TE = f[FS, RDI, NXI_{(t-1)}, ADV_{(t-1)}, MEI_{(t-1)}, ADV^2_{(t-1)}, D] \quad (7)$$

$$FS = f[TE, RDI, FA, MEI, NXI, TE^2] \quad (8)$$

$$RDI = f[TE, FS, NXI, PR, \left(\frac{K}{L}\right), TE^2, NXI^2] \quad (9)$$

The specified equation for TE is nonlinear in $ADV_{(t-1)}$, FS is nonlinear in TE and RDI is nonlinear in TE and NXI.

The justifications for the inclusion of the above-mentioned variables in TE equation have already been discussed above. The linkage between FS and its determinants is discussed below:

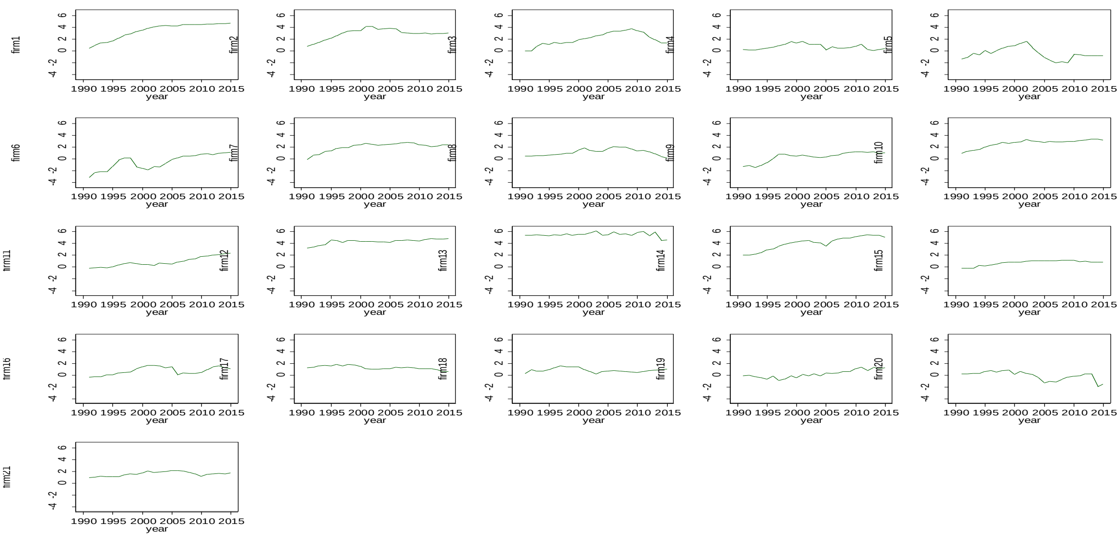
A positive relationship between TE and FS may occur because, with an increase in TE, the firm may produce more output, so there can be an increase in firm size. RDI may affect FS positively, possibly due to the fact that firms engaged in R&D can invent superior processes and technologies or produce better products employing the same level of input (Aghion &Howitt, 1992; Grossman &Helpman, 1991). Thus, firms may produce better and more products, thereby increasing their firm size. A positive relationship may exist between Firm Age and Firm Size as well as Advertising Intensity and Firm Size. Perhaps a firm staying in the market for a long period is capable of acquiring perfect market strategy and consumer faith and thus producing more, which may lead to a firm size increase. Also, firms that spend more on advertisement are more likely to introduce a new product easily, which increases sales, and fights market competition, which may insist firms produce more to meet the extra demand created by advertising, thereby increasing firm size.

The relation between RDI and the explanatory variables can be justified as follows:

TE may affect RDI positively or negatively. A positive relation may prevail between these two due to an increase in TE; the capability of firms through using their input efficiently may rise and produce more output, which can promote Research and Development Intensity. Also, there can be a possibility of a negative relationship, possibly due to several reasons such as improvement in the ability of the workers, better management decisions, adequate monitoring efforts, etc., which may lead to more and more production, thereby making firms more reluctant to invest in R&D and so RDI may fall. Positive relationship is expected between Firm size and RDI may be due to the reason that a larger firm can be able to exploit economies of scale which influence firms to increase RDI and further maintain economies of scale. A positive association between NXI in the previous period and RDI may exists possibly due to the fact that with increase in net export in the previous period the firm may generate extra profit from foreign market and increase RDI in the current period. It is hypothesized that higher the degree of mechanization in the production system, higher will be the R&D expense of the firm. On the other hand, Capital-labour Ratio may affect the R&D expense of the firm negatively due to underutilization of capital. Capital-labour Ratio (K/L) may be obtained for each sector by the ratio of capital to labour. Firm's profits are an important stimulus to, and source of funding for, R&D which in turn may lead to a positive relationship between profit and RDI. Profitability Ratio (PR) is obtained for each sector by the ratio of profit to sales.

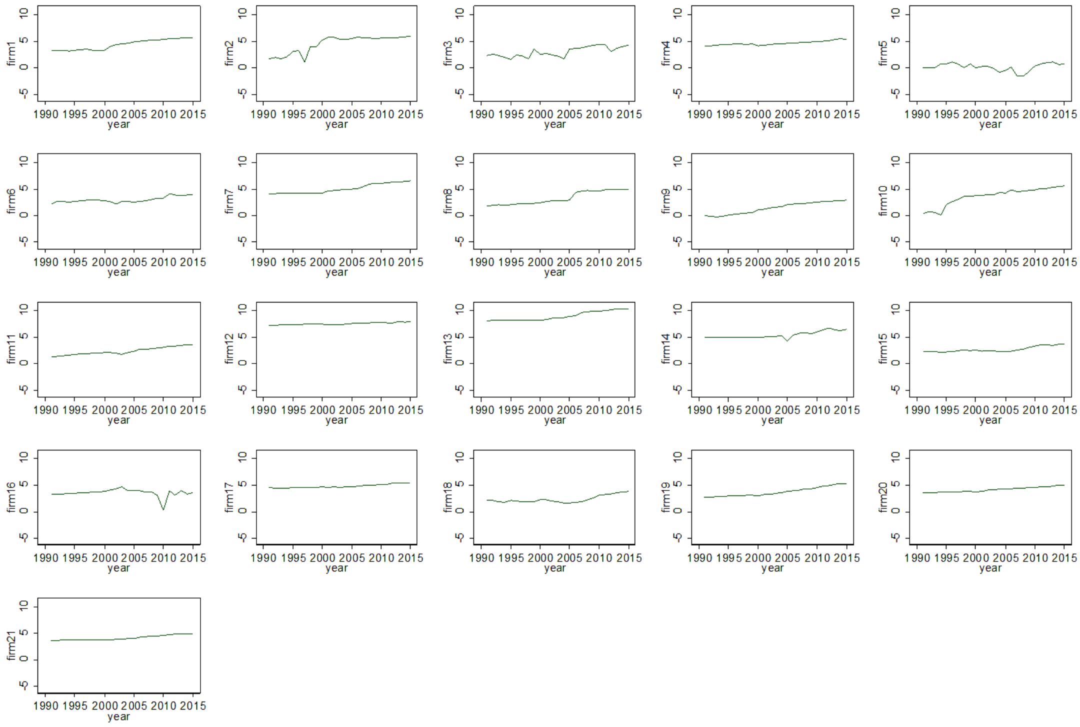
The identification of the model is tested in the presence of an exclusion restriction, and the models are overidentified. Estimation is done first by the two-step estimation method and then by applying the method of estimation of the panel model. Hausman's specification test is performed for each of the regressions, which strongly rejects the assumption of the random effect model and supports the assumption of the fixed-effect model.

Figure 3: Trend of Output of Sample Firms for the period 1991-2015



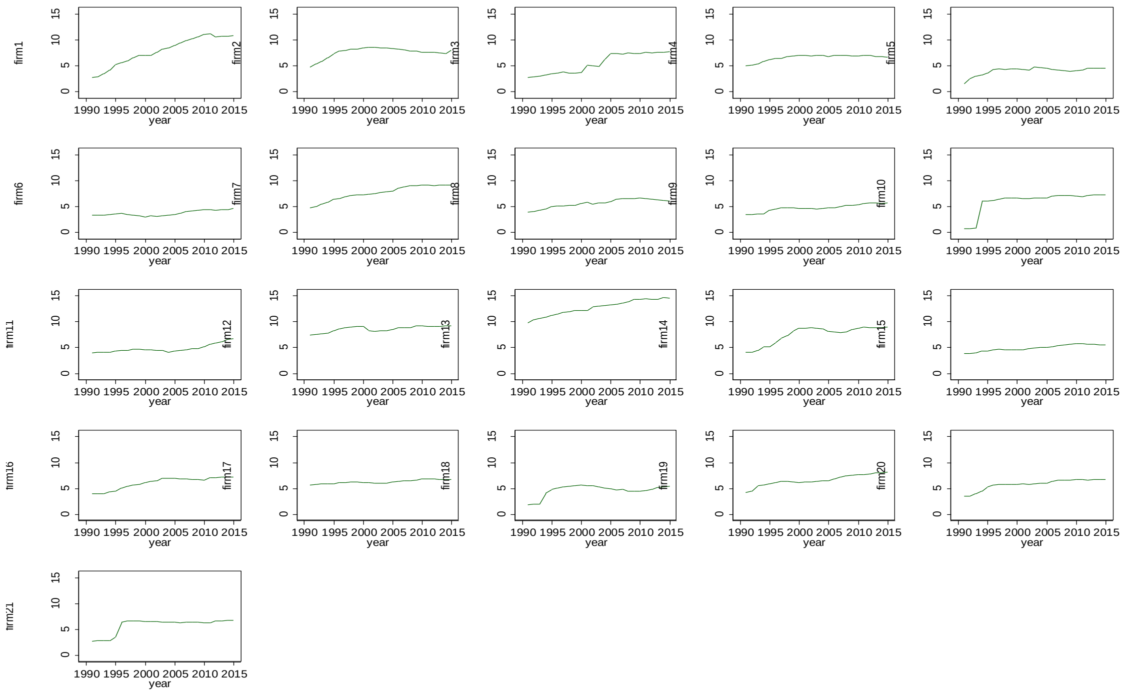
Source: Authors' own compilation

Figure 4: Trend of Employment of Sample Firms for the period 1991-2015



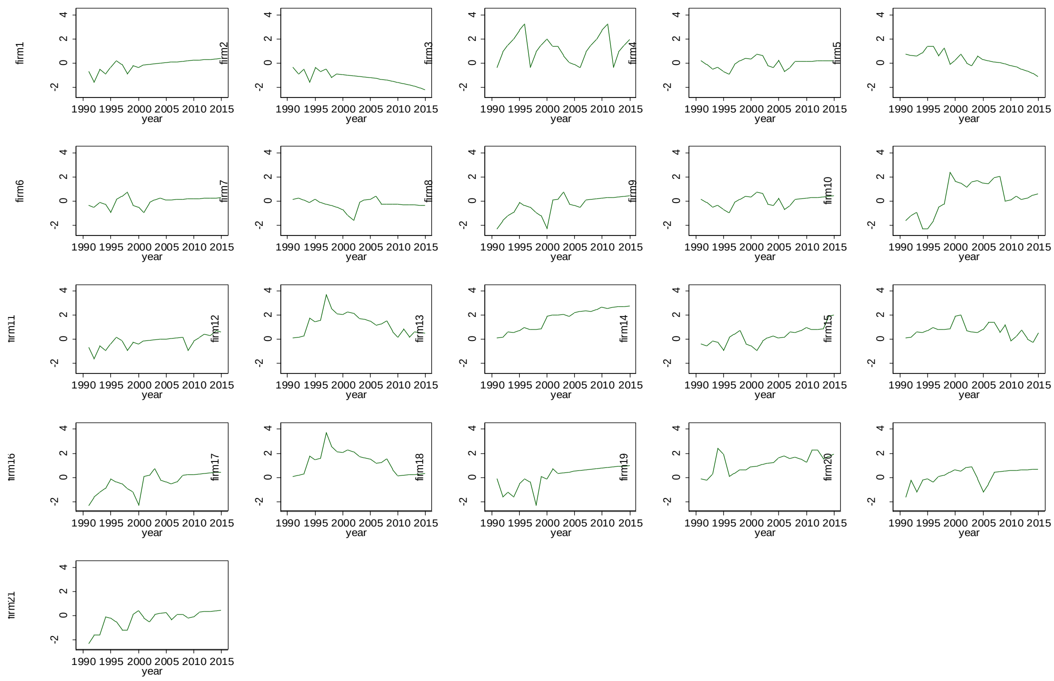
Source: Authors' own compilation

Figure 5: Trend of Capital Investment of Sample Firms for the period 1991-2015



Source: Authors' own compilation

Figure 6: Trend of R&D of Sample Firms for the period 1991-2015



Source: Authors' own compilation

4. Results and discussion

This Section 4 presents the results of analysis and discussion. Subsection 4.1 discusses the estimated results of Technical Efficiency and in subsection 4.2, the major factors affecting Technical Efficiency are presented. The econometric package used in the analysis is EViews 11.

4.1 Estimated Results of Technical Efficiency

The results of the OTE of the IFI firms are found, and their distribution is represented in Table 1. It is seen that, out of the 21 firms, only 9.52% are fully efficient, i.e., they are on the frontier with technical efficiency equal to one for the entire sample period, i.e., 1991 to 2015. The rest, 90.48% of the firms under study are not fully efficient, i.e., 23.81% of them produce less than 50% of the maximum producible output. 9.52% of firms have their mean TE in the range (0.600-0.700), and 19.05% of firms are producing 80 to 90% of the maximum producible output. The majority of firms, i.e., 38.10%, produce 90% to 99% of the maximum producible output. Table 2 shows that considering all 21 sample firms together, the mean TE ranges from 0.146 to 1. The grand mean of TE of the firms (GRM), i.e., the average of the mean TE of all the sample firms over the sample period 1991-2015, is 0.760, implying that on average the sector produces 76% of the maximum producible output. The percentage of firms with a mean TE below the grand mean is 33.33, and the rest, 66.67%, are above the grand mean of TE.

So, most of the firms (67%) have their mean TE above the GRM, suggesting good performance; the mean efficiency value is between 8 and 10 compared to the rest of the firms (33%), whose mean efficiency is between 0 and 7.

Table 1: Distribution of Firms Based on Output -Oriented TE Scores

Mean TE scores	Percentage of firms
Below 0.500	23.81
0.500-0.600	0
0.600-0.700	9.52
0.700-0.800	0
0.800-0.900	19.05
0.900-0.999	38.10
1	9.52

Source: Authors' own calculation

Table 2: Output Oriented Technical Efficiency

Variable	Range of Mean TE	Grand Mean of TE (GRM)	Percentage of Firms below the GRM	Percentage of Firms above the GRM
TE	0.146-1	0.760	33.33	66.67

Source: Authors' own calculation

4.2 Factors affecting Technical Efficiency of IFI

A second-stage panel regression has been carried out to explain the OTE of IFI. The variables FS, RDI, NXI, ADV, and MEI are considered as possible determinants of TE. It may be mentioned that all the estimated equations in the model are found to be nonlinear. In the model, there are three equations, namely Technical Efficiency, Firm Size and RDI.

For TE, the Advertising Intensity of the previous period has an inverted U-shaped relationship, whereas Firm Size, RDI, Net Export Intensity of the previous period and Marketing Intensity of the previous period are linearly related with TE. As the marginal effect of Advertising Intensity of the previous period is found to be positive, it implies that this variable has a positive relationship with TE. Thus, the result suggests that TE increases with increases in ADVt-1, FS, RDI, NXIt-1 and MEIt-1. The relationship between Advertising Intensity of the previous period and TE is inverted U-shaped. The result may be due to the fact that firms spending more on advertisement are more likely to introduce a new product into the market easily, which increases sales, fights market competition, enhances good-will with consumers and educates them, and thus increasing efficiency. But after some threshold point increase in advertising, technical efficiency may decrease due to a loss of consumer goodwill with more advertisement. Firm size is positively related to TE as large firms are more efficient due to the scale economies, imperfections in the capital market, and market power (Kumar, 2003). A positive relationship is found between RDI and TE; it may be that research and development generates new technologies and enhances a firm's ability to exploit existing technologies, thereby increasing TE. With the rise in net export intensity, technical efficiency is rising, which may be due to knowledge spillover from international contacts and spillovers from technology diffusion. An increase in marketing activities indicates an effort to strengthen the firm's brand and product image, which may lead to higher revenue and in turn enhance output efficiency (Hurwitz &Caves, 1988; Leffler, 1981). The fact that the dismantling of MFA has a significant negative effect on technical efficiency may be due to the failure of these firms to match the competitive pressures in terms of price and quantity from different countries. In this unfavorable situation, the firms are unable to achieve economies of scale in production, which may lead to a decline in technical efficiency.

In the case of Firm Size, Technical efficiency has a nonlinear, i.e., inverted U-shaped relationship with FS; perhaps with an increase in efficiency, the firm uses its input efficiently and produces more output, so there can be an increase in firm size; but after some threshold level with an increase in TE, FS decreases possibly due to the failure to reap the benefits instantly of huge investments in sophisticated technology and better management, so there can be a fall in output and hence a fall in firm size. The marginal effect of technical efficiency on FS is found to be positive, whereas RDI, Firm Age, Marketing Intensity and Net Export Intensity are linearly related to FS. Firms engaged in R&D can invent superior processes and technologies or produce better products employing the same level of input (Aghion &Howitt, 1992; Grossman &Helpman, 1991), thereby increasing profit and further production, which may increase firm size. A positive relationship being found between FA and FS may be possible that firms staying in the market for a longer period can acquire perfect market strategy, smooth buyer-supplier linkage, and consumer faith, which may lead to an increase in firm size. More marketing activities indicate an effort to strengthen the firm's brand and product image, which may lead to higher revenue (Hurwitz &Caves, 1988; Leffler, 1981), which may promote FS, and an increase in Net Export may mean demand for domestic goods in foreign markets increases, thereby raising production, which can boost firm size.

For the Research and Development Intensity (RDI), it can be inferred that technical efficiency and Net Export Intensity have a nonlinear relationship with RDI whereas Firm Size, Profitability ratio and Capital-labour ratio are linearly related. The relationship between technical efficiency and RDI is inverted U-shaped, possibly due to an increase in TE, the capability of firms through using their input efficiently may rise and produce more output, which can promote RDI, but after some threshold level with an increase in TE, RDI decreases if the rise in TE of the firms is due to an improvement in the ability of the workers, better management, adequate monitoring efforts, etc. This may lead to more and more production, making firms more reluctant to invest in R&D, and so RDI may fall. As the values of the marginal effects of technical efficiency and Net Export Intensity are found to be positive, does this imply that these variables have a positive relationship with RDI? The net effect of net export intensity on RDI is positive. Perhaps an increase in net exports may increase RDI by generating extra profit from the foreign market. A positive relationship is found between FS and RDI. Possibly, a larger firm can exploit economies of scale, which influence firms to increase Research and Development Intensity. A positive relationship is also found between PR and RDI. With the increase in PR, firms may have more surplus funds in hand, which may stimulate research and development intensity. There exists a positive relationship between the capital-labor ratio and RDI, making it possible that the capital-intensive industries have a high potential to generate more profits and keep strategies for high growth and the usage of high technology (Seenaiah & Rath, 2018), thereby increasing RDI.

The present paper thus recommends an increase in Firm Size and higher Research and Development Intensity, Net Export Intensity, Advertising Intensity, and Marketing Intensity for encouraging OTE of IFI. Also, it is found that by staying in the market for a longer period, firms can acquire perfect market strategy, smooth buyer-supplier linkage, and consumer faith, which may lead to an increase in the firm size, thereby increasing OTE. With the increase in PR, firms may have more surplus funds in hand, which may stimulate research and development intensity and thus OTE. Capital-intensive industries have a high potential to generate more profits and keep strategies for high growth and usage of high technology (Seenaiah & Rath, 2018), thereby increasing RDI and hence OTE.

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

Explanatory Variable	**Efficiency Equation**	**Firm Size Equation**	**Research and Development Intensity Equation**
	Coefficient	**Coefficient**	**Coefficient**
C	0.762***	-0.871***	-0.479***
	(18.574)	(-7.524)	(-41.653)
FS	0.265***		0.649***
	(2.684)		(39.282)
RDI	0.762***	0.057***	
	(7.403)	(7.331)	
TE		2.112***	1.114***
		(7.075)	(41.003)
FA		0.002***	
		(42.052)	
MEI		0.031***	
		(40.956)	
NXI		0.0001***	2.30E-05***
		(10.787)	(4.112)
PR			8.28E-05***
			(13.186)
K/L			0.0002***
			(83.002)
$NXI_{(t-1)}$	0.0004***		
	(9.263)		
$ADV_{(t-1)}$	0.077***		
	(9.533)		
$MEI_{(t-1)}$	0.070***		
	(12.982)		
TE^2		-1.266***	-0.666***
		(-7.518)	(-4.822)
NXI^2			4.35E-06***
			(30.261)
$ADV_{(t-1)}{}^2$	-0.012***		
	(-8.557)		
D	-0.099***		
	(-59.894)		
Marginal Effect of FS	0.265		0.649
Marginal Effect of RDI	0.762	0.057	
Marginal Effect of FA		0.002	
Marginal Effect of MEI		0.031	
Marginal Effect of PR			8.28E-05
Marginal Effect of K/L			0.0002
Marginal Effect of $NXI_{(t-1)}$	0.0004		

Explanatory Variable	Efficiency Equation	Firm Size Equation	Research and Development Intensity Equation
	Coefficient	Coefficient	Coefficient
Marginal Effect of $MEI_{(t-1)}$	0.070		
Marginal Effect of TE		0.171 (21.377***) ^	0.094 (30.346***) ^
Marginal Effect of NXI			0.00004 (4.825*) ^
Marginal Effect of $ADV_{(t-1)}$	0.075 (16.472***) ^		
Marginal Effect of D	-0.099		
Adjusted R-squared	0.895	0.905	0.923
F-statistic	639.068	832.965	898.314
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

5. Conclusion

The present paper estimates the OTE of IFI for the period 1991-2015, using DEA. Side by side, it also finds out the determining factors of OTE. The novelty of the present paper is that it takes care of the possible simultaneous relationship between the different variables affecting OTE.

The majority of the firms in the IFI, i.e., 67%, shows good performance, and on average, the IFI produces 76% of the maximum producible output. This suggests that there is a considerable difference in performance among firms doing well (67%) and other firms (33%). Firm size, Research and Development Intensity, Net Export Intensity, and Marketing Intensity are the encouraging factors of TE. TE is found to depend positively on Advertising Intensity in the previous period. It is observed that the effect of dismantling MFA has a negative and significant effect on Technical Efficiency. The present paper reveals that to promote the technical efficiency of IFI, any policy changes that will lead to an increase in Firm Size, Research and Development Intensity, Net Export Intensity, Advertising Intensity, and Marketing Intensity should be emphasized. Also, firms staying in the market for a longer period, and acquiring higher profits, as well as capital-intensive firms, will be more efficient in IFI.

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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