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Evaluating Input Oriented Technical Efficiency in the Indian Machinery Sector: Insights from the Post-Reform Era

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Abstract : This study evaluates the Input-Oriented Technical Efficiency (ITE) of the Indian machinery sector during the post-reform period, utilizing a Non-parametric Data Envelopment Analysis (DEA) based on firm-level data from the CMIE Prowess Database, spanning March 1995 to March 2016. The findings reveal a decline in average ITE from 0.895 to 0.854 over the period. The highest average ITE (0.936) occurred in 1998, while the lowest (0.854) was in 2016. Only around 17% of the sampled firms were operating efficiently. The results indicate that these firms could have maintained the same output level while reducing raw material inputs by 43.77%, energy and water usage by 13.639%, labour by 31.647%, land by 2.843% and capital by 85.947%. A panel regression was conducted to explore the relationship between ITE and factors such as advertising intensity (ADV), marketing intensity (MKT), R&D intensity (RD), and net exports intensity (NX). The analysis suggests that increases in ADV, MKT, RD, and NX improve firm performance (i.e., ITE), and ITE, in turn, significantly influences these strategic variables in the Indian machinery industry. The study also proposes policy recommendations to enhance ITE in this sector.

Keywords: Manufacturing Sector, Indian Economy, Data Envelopment Analysis

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India's global ranking in machinery production fell from 8th in 2010 to 10th in 2014, and it remains a net importer of machinery, despite some growth in exports. The industry faces challenges such as a growing reliance on imports due to domestic manufacturers' inability to meet rising demand. The USA is the largest market for India's machinery exports, followed by the UAE, Germany, and the UK, while China remains the top import source.

The 2016 National Capital Goods Policy aims to boost domestic production, employment, and exports in the sector. However, low technology and scale, especially among MSMEs, along with limited R&D, pose barriers to growth. Key sectors like electrical equipment and textile machinery rely on outdated technology, and inadequate investment in innovation hampers the industry's overall development.

There are two alternative concepts of efficiency. One is allocative efficiency and the other one is technical efficiency. The present study focuses on technical efficiency. Technical efficiency can be measured either input-oriented (the ratio of minimum level of input required to produce a given level of output to the actual input used to produce that given level of output) or output-oriented approach (the ratio of actual output produced to the maximum level of output that can be produced given the input usage). The present study will consider only input oriented approach.

A review of existing studies shows mixed outcomes on the efficiency of Indian manufacturing post-reforms. Driffield and Kambhampati (2003) found efficiency improvements in five out of six manufacturing sectors. Mazumdar and Rajeev (2009) indicated that higher export earnings did not guarantee improved efficiency in Indian pharmaceutical firms. Bhandari and Maiti (2012) observed a positive link between firm size and technical efficiency in Indian leather firms, while Kumar and Arora (2012) reported a significant decline in technical efficiency in the post-reform period. Saravanakumar and Kim (2012) noted that reforms improved efficiency in heavy industries but not in light industries. Akram and Illiyan (2021) indicate that the main driver of high performance in the engineering goods industry, which achieved an 8.8% output growth, is primarily input-driven growth (8.2%) during the post-reform period. However, the impact of technological change was minimal (0.1%), and technical efficiency

actually declined (-0.2%). This underperformance is attributed to sluggish progress, outdated technology, and inefficient resource use within the Indian economy. Mukherjee & Ray (2005) used Data Envelopment Analysis on state-level manufacturing data from 1986-87 to 1999-00 to examine efficiency changes. This research finds no significant shift in state efficiency rankings or evidence of convergence post-reform.

Parameswaran (2004) revealed technological progress in Indian capital goods industries during the 1990s but a decline in technical efficiency. Mazumdar, Rajeev, and Ray (2012) found that while Indian pharmaceutical firms efficiently utilized inputs, output efficiency declined between 1991 and 2005. Bhandari and Ray (2011) suggested that firm size directly impacts technical efficiency in the Indian textile industry, advocating for consolidation among smaller firms to enhance efficiency.

There exists a nexus relationship between the Indian firms' performances and different strategic variables in the post-reform era (Chen & Ibhagui (2019), Pyper et al. (2022), Gakii & Maina (2019) etc.). Different strategic variables may be endogenous in nature. For example, Advertising Intensity (ADV), Marketing Intensity (MKT), R&D Intensity (RD) and Net Export Intensity (NX) may not only affect the firms' performance indicators like input oriented technical efficiency (ITE) but in turn they may get affected by this performance indicator. Thus, there may be inter-connection between these variables. There is dearth in the studies highlighting these simultaneous relationships. The present study fills up this gap and contributes to the literature in this direction. The study finds out the determinants of ITE in a simultaneous panel set up. For determinant analysis, a simultaneous panel model as developed by Baltagi (EC2SLS random-effects Instrumental Variable regression) has been performed for ITE Block considering the endogenous variables ITE, ADV, MKT, RD and NX. This type study is very important for framing appropriate policies to boost up the performance level of Indian chemical firms. The paper unfolds as follows: Section 2 reports data sources. Section 3 presents the estimated results of input oriented technical efficiency of firms. Section 4 represents the determinant analysis and Section 5 concludes the study.

2. Data Sources

Data regarding the Input-Output variables for estimating ITE has been collected from CMIE Prowess Database for the time period March, 1995 – March, 2016. Total number of machinery firms incorporated is 150.

The study outlines a production technology with one output and five inputs. The output is the firm's total sales, adjusted by the Wholesale Price Index (WPI) for manufacturing products (base year 1993-94 = 100). The five inputs are: (i) Raw materials (including expenditure on materials, stores, and spares), adjusted using the WPI for manufacturing products, (ii) Energy and water (measured by expenditure on power, fuel, and water), adjusted by the WPI for power and fuel, (iii) Labor (based on wages and salaries), with nominal wages adjusted by the WPI, (iv) Land (measured by rent and lease payments), adjusted by the WPI, and (v) Capital (measured by the value of net fixed assets), adjusted using the WPI for machinery (base year 1993-94 = 100). Data used for determinant analysis has also been collected from CMIE Prowess Database for the time period March, 1995 – March, 2016.

3. Estimated results of Input Oriented Technical Efficiency of Indian Machinery Firms

The input-oriented efficiency score of the companies is obtained on the basis of a computer program DEAP Version 2.1, developed by Tim Coelli.

Table 1. Mean Input Oriented Technical Efficiency of the Indian Machinery Firms

Year	Machinery	Year	Machinery
1995	0.895	2006	0.919
1996	0.903	2007	0.918
1997	0.905	2008	0.920
1998	0.936	2009	0.907
1999	0.905	2010	0.894
2000	0.933	2011	0.902

2001	0.879		2012	0.882
2002	0.895		2013	0.879
2003	0.857		2014	0.869
2004	0.866		2015	0.893
2005	0.904		2016	0.854
➔			Grand Mean	0.896

□Source: Compiled by the Author

For the sample firms included in machinery industry, mean ITE has been decreased from 0.895 to 0.854 during the study period (1995-2016). The mean ITE is the highest (0.936) in 1998 and the lowest (0.854) in 2016.

Table 2. Percentage of Efficient firms in Indian Machinery Industry

Indian Machinery Industry	**% of firms**
Efficient	17
Inefficient	83

□Source: Compiled by the Author

Table 2 shows that 17% of the total sample firms were producing efficiently. This means that their efficiency score is equal to 1 and others are producing below the production frontier.

Table 3. Mean Input Slacks

Industry	Raw materials input	Energy & water input	Labour	Land	Capital
Machinery	43.77	13.639	31.647	2.843	85.947

□Source: Compiled by the Author

Table 3 represents that the same amount of output can be produced by reducing raw materials input 43.77%, energy & water input by 13.639%, labour by 31.647%, land by 2.843% and capital by 85.947%. Thus, this result is an instance of inefficient utilization of scarce resources by the Indian machinery firms over the study period.

4. Determinants of Input Oriented Technical Efficiency (ITE)

A second stage panel regression has been carried out to relate the ITE of the Indian chemical firms with the strategic variables perused by firms as well as firms' characteristics namely R&D Intensity, Net Export Intensity, Advertising Intensity, Marketing Intensity, Age, Diversification Index and Size of the company. The explanations for the inclusion of different explanatory variables can be summarized as follows:

(i) Advertising Intensity (ADV):

This variable is represented by the ratio of advertising expenditure to total sales. Advertising helps reduce price competition by promoting product differentiation in consumer goods industries. Goldar et al. (2004) and Carod and Blasco (2004) highlighted the link between advertising intensity and technical efficiency in Indian engineering goods and Spanish manufacturing firms, respectively.

(ii) Marketing Intensity (MKT):

This variable is the ratio of marketing expenditure to total sales, serving as a proxy for product differentiation. Kao et al. (2006) found a direct relationship between marketing

expenditure and returns, which can manifest as increased sales or profits.

(iii) R&D Intensity (RD):

This variable is the ratio of R&D expenditure to total sales. Several studies, including Ferrantino (1995), Driffield and Kambhampati (2003), and Mazumder et al. (2010), highlight the connection between R&D activities and firm efficiency in Indian industries.

(iv) Net Export Intensity (NX):

Exporting is widely believed to boost firm efficiency, supported by theories that link international market exposure with increased efficiency through innovation and technology transfer. Studies by Chen and Tang (1987), Sun et al. (1999), Walujadi (2004), and Mok et al. (2010) provide evidence of pre-export benefits. Additionally, the World Bank reports highlight that reduced import restrictions in India have improved access to advanced technologies, thereby enhancing efficiency. Goldar et al. (2004) and Mazumder et al. (2010) confirm a direct link between imports and technical efficiency. This paper will explore the relative impact of exports versus imports on efficiency using net export intensity (NX) as a key variable.

(v) Diversification Index (DIVIND):

DIVIND of a particular industry group captures the effect of market structure on efficiency of the firms. DIVIND is the reciprocal of concentration ratio. The Herfindahl Index or Concentration Index is calculated as follows: $H = \Sigma s_i^2$; where s_i is the market share of the i^{th} firm in the market and N is the number of firms.

Some researchers expect a negative relationship between Concentration Ratio (CR) and efficiency, as competition may drive cost reduction and technological progress. Others argue that large firms with secure markets benefit from increased efficiency. Empirical studies offer mixed results and no clear consensus (Katz, 1969; Kendrick, 1973).

(vi) Age:

There are differing views on how a firm's age impacts its performance. One perspective suggests that older firms perform better due to their greater experience (Stinchcombe, 1965).

Conversely, another view argues that older firms may struggle with adapting swiftly to changing economic conditions, whereas younger firms can adjust more quickly and effectively (Marshall, 1920).

The present study has divided the sample companies into two groups:

Agedum = 1, if Mean Age of the firm < Grand Mean Age

= 0, Otherwise

(vii) Size:

Efficiency can vary with firm size, as larger firms often access cheaper, higher-quality inputs and benefit from economies of scale. This allows them to optimize operations and outperform smaller firms (Penrose, 1959). The present study divides the sample basis on investment into three groups, on the basis of Investment in plant & machinery or equipment according to MSME Classification:

Smalldum = 1, if mean investment < 5 Cr. rupees

= 0, otherwise

Mediumdum = 1, if mean investment < 10 Cr. rupees

= 0, otherwise

Largedum = 1, if mean investment > 10 Cr. rupees

= 0, otherwise

In order to avoid dummy variable trap, Mediumdum has been dropped.

It may be possible that the effect of different explanatory variables may be non-linear in nature. To get this effect, the sole effect of different variables, their square terms and the joint effect of different variables will be incorporated. The effects of the lag value (one year lag) of different strategic variables (i.e. the effects of different strategic variable in the previous period) have also been considered.

4.1 Explaining the Factors Significantly influencing ITE of the Indian Machinery Firms:

The Results from a Two Stage Least Square Type Approach in a Simultaneous Panel Model

The determinant analysis is based on the estimation of a **simultaneous panel model** consisting of the equations specifying the determination of **ITE, ADV, MKT, RD** and **NX**. Since the present study is mainly interested in finding out the determinants of ITE, to keep my article within limit, I am only reporting the summary result regarding the **effects of different variables on ITE and the effect of ITE on different strategic variables**.

The estimated ITE of Indian machinery firms and also the other endogenous variables explaining the ITE corresponding to ITE block can be visualized from Table 4 to Table 8.

Table 4. Factors explaining ITE from a Simultaneous Equation Panel Model: The ITE Block

Endogenous Variable: ITE

Independent Variable	**Coefficient**	**z-value**	**p>|z|**
ADV	-.0005247	-1.76	0.078
$(ADV)^2$	4.94e-07	1.68	0.094
ADVlag	.0001862	2.24	0.025
ADV*MKT	6.95e-07	2.68	0.007
RD	-.0007195	-6.43	0.000
$(RD)^2$	2.55e-07	4.78	0.000
NX*RD	6.88e-09	2.21	0.027
DIVIND	-.0013776	-2.13	0.034
Smalldum	-.0900051	-2.59	0.010
Wald chi2 =	140.31	Prob > chi2	= 0.0000

Determinants	Marginal effects
ADV	0.0013
MKT	0.0006
RD	0.0047
NX	0.0001

The first equation of ITE Block: The estimated ITE relation

The analysis in Table 4 reveals that ITE is positively influenced by previous-period ADV, with increases in past ADV boosting current ITE.

For current-period ADV, there is a U-shaped relationship with ITE. While the direct effect of ADV is negative, its squared term has a positive impact. Initially, ADV does not affect ITE, but once it surpasses a certain threshold, its positive effect on ITE becomes evident.

The interaction of ADV and MKT also positively affects ITE, indicating that combined spending on ADV and MKT enhances ITE. Thus, the marginal effects of both ADV and MKT are positive.

Current-period R&D shows a U-shaped relationship with ITE. Initially, increased R&D does not impact ITE, but once it exceeds a certain level, its positive effect on ITE is realized. NX has a positive marginal effect on ITE, suggesting that exports are more influential than imports. DIVIND negatively affects ITE; as market concentration increases, ITE improves. Smalldum also negatively impacts ITE, meaning that larger firms generally exhibit higher ITE compared to smaller firms.

Table 5. Factors explaining ADV behaviour from a Simultaneous Equation Panel Model: The ITE Block

Endogenous Variable: ADV

Independent Variable	Coefficient	z-value	p>|z|
ITE	11.44218	3.38	0.001
MKT	.2867231	10.55	0.000
$(MKT)^2$	.0002693	16.59	0.000
RD	1.005278	14.59	0.000
$(RD)^2$	-.0002963	-18.78	0.000
NX	.002686	17.45	0.000
NXlag	.0013359	14.30	0.000
DIVIND	-.1311036	-1.39	0.165
Agedum	1.760317	1.25	0.210
Largedum	4.274417	2.19	0.028
Wald chi2 = 13405.68		Prob > chi2 = 0.0000	
Determinants		Marginal effects	
ITE		11.4422	
MKT		0.3052	
RD		1.0044	
NX		0.0027	

The second equation of ITE Block:The estimated ADV relation

Table 5 shows that ADV is positively related to the current-period ITE (Internal Technical Efficiency), as well as to NX (net exports) from both the current and previous periods. Increases in these factors raise current-period ADV.

Current-period MKT has a positive non-linear relationship with ADV, with increasing MKT boosting ADV.

Current-period RD exhibits an inverted U-shaped relationship with ADV. Initially, higher RD increases ADV, but beyond a certain point, RD negatively affects ADV. Overall, the marginal effect of RD on ADV is positive.

Agedum positively influences ADV, with younger firms generally having higher ADV levels than older firms. DIVIND negatively impacts ADV; as market concentration increases, ADV rises. Largedum also positively affects ADV, indicating that larger firms tend to have higher ADV levels compared to smaller firms.

Table 6. Factors explaining MKT behaviour from a Simultaneous Equation Panel Model: The ITE Block

Endogenous Variable: MKT

Independent Variable	Coefficient	z-value	p>|z|
ITE*ADV	.688254	6.74	0.000
ADV	.2440194	2.70	0.007
$(ADV)^2$	-.0000938	-1.83	0.067
ADVlag	.3724316	14.61	0.000
RD	.026809	1.01	0.311
$(RD)^2$	.0000591	8.14	0.000

RDlag	.5010203	25.38	0.000
RD*ADV	.0002971	14.44	0.000
NX	-.0013455	-4.31	0.000
NXlag	-.0026896	-17.52	0.000
Wald chi2 = 26710.14		Prob > chi2 = 0.0000	
Determinants		Marginal effects	
ITE		6.0830	
ADV		0.8257	
RD		0.0243	
NX		-0.0013	

The third equation of ITE Block:The estimated MKT relation

Table 6 shows that MKT is positively related to ADV and RD from the previous period, meaning increases in past ADV and RD boost current MKT. MKT is negatively related to NX in both the current and previous periods, indicating that imports outweigh exports.

Current-period ADV has an inverted U-shaped relationship with MKT, where initial increases in ADV raise MKT, but beyond a certain point, ADV negatively impacts MKT.

There is a positive composite effect of ITE and ADV on MKT, where increased ADV boosts ITE, thereby raising MKT. Similarly, a joint effect of RD and ADV also positively influences MKT, with combined spending on RD and ADV increasing MKT.

Current-period RD has a non-linear positive relationship with MKT, suggesting that higher RD enhances MKT. Overall, the marginal effects of ITE, ADV, and RD on MKT are positive.

Table 7. Factors explaining RD behaviour from a Simultaneous Equation Panel Model: The ITE Block

Endogenous Variable: RD

Independent Variable	Coefficient	z-value	p>|z|
ADV	-2.664827	-11.52	0.000
$(ADV)^2$	.0018637	11.68	0.000
ITE*ADV	3.326782	11.14	0.000
MKT	1.056138	18.24	0.000
$(MKT)^2$	.0009146	21.20	0.000
MKTlag	.2517518	8.74	0.000
NX	.0102469	14.09	0.000
NXlag	.0043023	3.97	0.000
ITE*NXlag	-.0025408	-1.39	0.163
$(ITE*NXlag)^2$	3.11e-07	4.32	0.000
Agedum	10.1763	1.42	0.155
Wald chi2 = 11694.05		Prob > chi2 = 0.0000	
Determinants		Marginal effects	
ITE		0.2997	
ADV		0.3385	
MKT		1.0928	
NX		0.0102	

NXlag	0.0279
ITE*NXlag	0.0076

The fourth equation of ITE Block: The estimated RD relation

Table 7 shows that RD is positively associated with MKT from the previous period and NX from the current period.

Current-period ADV has a U-shaped relationship with RD, where ADV positively impacts RD only beyond a certain threshold.

A joint effect of ITE and ADV exists; increased ADV boosts ITE, which in turn raises RD.

NX from the previous period has a direct positive effect on RD. Additionally, an interaction between current-period ITE and previous-period NX shows that previous NX enhances current ITE, which then increases RD. Thus, the marginal effects of current-period ITE, ADV, and previous-period NX on RD are positive.

Current-period MKT has a non-linear positive relationship with RD, with higher MKT leading to increased RD.

Agedum also positively affects RD, indicating that younger firms tend to invest more in RD compared to older firms.

Table 8. Factors explaining NX behaviour from a Simultaneous Equation Panel Model: The ITE Block

Endogenous Variable: NX

Independent Variable	Coefficient	z-value	p>|z|
ITE	-3.673035	-10.24	0.000
$(ITE)^2$	.0141739	9.97	0.000
ADV	.095715	1.25	0.210

$(ADV)^2$	.0011231	17.21	0.000
ADVlag	.3707653	14.24	0.000
MKT	-.6038238	-11.97	0.000
$(MKT)^2$	4.91e-06	0.22	0.825
MKTlag	.1245413	2.63	0.009
RD	.0237506	0.53	0.598
$(RD)^2$	.0000531	4.19	0.000
RDlag	.055947	3.90	0.000
REER	-.570493	-2.74	0.006
DIVIND	-.2529001	-1.04	0.299
Wald chi2 = 6797.95		Prob > chi2 = 0.0000	
Determinants		Marginal effects	
ITE		-3.6520	
ADV		0.1174	
MKT		-0.2006	
RD		0.0228	

The fifth equation of ITE Block: The estimated NX relation

Table 8 shows that NX is positively related to ADV, MKT and RD from the previous period, meaning increases in these past factors boost current NX. NX is negatively related to REER.

Current-period ITE has a U-shaped relationship with NX; while the direct effect of ITE is negative, its squared term has a positive effect. This suggests that NX benefits from ITE only

when it exceeds a certain threshold. Currently, the marginal effect of ITE on NX is negative due to ITE being below this threshold.

Current-period RD and ADV both exhibit positive non-linear relationships with NX, with increases in RD and ADV raising NX.

Current-period MKT has a U-shaped relationship with NX. The positive impact of MKT on NX becomes apparent only beyond a certain level, and the marginal effect is negative since the average MKT is below this threshold.

DIVIND negatively impacts ITE, and as market concentration increases, NX rises.

5. Conclusion & Policy Suggestions

This paper examines the level of Internal Technical Efficiency (ITE) and its determinants in the Indian machinery industry post-reform. The average ITE for the sample is 0.896, which decreased from 0.895 to 0.854 between 1995 and 2016. The highest ITE was 0.936 in 1998 and the lowest was 0.854 in 2016. Only 17% of the firms were efficient. It is noted that Indian machinery firms are not using resources efficiently; they could reduce inputs—raw materials by 43.77%, energy & water by 13.64%, labor by 31.65%, land by 2.84%, and capital by 85.95%—while maintaining output.

The analysis indicates that current-period ADV, MKT, RD and NX positively affect ITE. Increases in these factors boost current-period ITE. Furthermore, ITE positively impacts ADV, MKT, and RD, suggesting that improved ITE enhances these factors, which in turn further increases ITE. ITE has a U-shaped relationship with NX, where ITE's sole effect is negative, but its squared term is positive, indicating that the positive effect on NX will be realized only beyond a certain ITE level. To improve NX, further increases in ITE are recommended for the Indian machinery industry.

To improve internal technical efficiency (ITE) in the Indian machinery industry, policies could focus on supporting R&D through tax breaks, grants, or low-interest loans to foster innovation. Government support for advertising, especially for small and medium firms, would help strengthen brand presence and competitiveness. Additionally, easing regulations for domestic and export market entry and providing phased export incentives could enhance market expansion and efficiency. Finally, subsidies for adopting resource-efficient technologies and promoting resource optimization in production would help reduce input waste.

The one limitation of the article may be that while explaining efficiency, the Non-parametric DEA has been used. However, the literature supports that the alternative method of estimation is Parametric Stochastic Frontier Production Function approach to explain efficiency. Thus, the additional agenda of research may be to carry out the whole analysis of the current paper using Parametric Stochastic Frontier Production Function approach to verify the robustness of the result. This is agenda of my future research.

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