

# Efficiency of Indian Organized Manufacturing in Liberalized Regime: A Stochastic Frontier Approach

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*This paper attempts to estimate technical efficiency of Indian manufacturing industries across fifteen major states by estimating a time varying stochastic frontier production function and inefficiency effects model using panel data. The study covers the time period from 1993 to 2011 and reveals that there is an increasing trend of technical efficiency across the states. The Indian industrial sector recorded an average technical efficiency of 0.663. The estimated parameters of the translog production model using maximum likelihood method are statistically significant at conventional levels though their signs differ. The likelihood ratio test statistic rejects the Cobb-Douglas production technology as description of the database given the specification of the translog formulation.*

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## Introduction

Manufacturing is an important sector in the Indian economy comprising about 31% of the non-agricultural sector, which makes up 75% of the total GDP in India (Kaliranjan & Bhide, 2004). India's post-Independence development plans have emphasized industrialization as a very important instrument for sustained growth. Its sustained growth is crucial for generating employment opportunities required to absorb the rapidly expanding workforce. Industrialization plays a crucial role in the process of economic development of developing economies. At present, the share of industry in total employment increased from 16.2 per cent in 1999-2000 to 21.9 percent in 2009-10. A significant development in the Indian economy in the post 1990s period is the acceleration of the reform process initiated in the 1980s.

The reforms were initiated to improve the efficiency, productivity and international competitiveness of Indian industry. The reform process was more aggressively pursued during the 1990s. The sole

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objective of these highly liberalized policies was to augment productivity and efficiency in Indian industries by creating a competitive environment. Economic performance of a unit is generally supposed to be reflected in its productivity which is measured by the ratio of its output to the inputs. The efficiency term implies the maximum output obtained from utilizing the available inputs. Efficiency can be increased by minimizing inputs while holding output constant or by maximizing output while holding inputs constant or a combination of both. Productive efficiency can be determined by estimating the best practice production frontier and individual states' aggregate manufacturing industries.

### Review of Literature

A vast number of empirical applications have contributed to estimate technical efficiency of aggregate manufacturing sector as well as across of the states in India. Raj and Natrajan (2008) examined the technical efficiency in the unorganized manufacturing sector of Kerala and depicted the existence of a high level of technical inefficiency due to which their potential level has reduced significantly. Kumar (2005) endeavored to analyze regional variations in technical efficiency of Indian manufacturing sector using the method of stochastic frontier analysis. The

results revealed wide variations in the technical efficiency of manufacturing sectors of different states. Mukherjee and Ray (2004) analyzed the state level data of the manufacturing sector of India for the period 1985-86 to 1999-00 in order to study the efficiency dynamics of manufacturing sector during pre and post reforms years. Bhandari and Maiti (2007) has fitted translog stochastic frontier production function to firm level cross-sectional data on India's textile firms for selected five years to estimate technical efficiency of firms. They conclude that public sector firms are found to be relatively less efficient. Bhandari and Maiti (2012) attempt to estimate technical efficiency of individual leather producing firms for some years by applying two conventional methods viz. Data Envelopment Analysis and Stochastic Frontier Analysis. The findings of the study imply significant variation in technical efficiency across firms in different groups of states as well as under different organized structure.

At the very outset, the present study estimates efficiency scores achieved by the states during the period 1994-95 to 2010-11 using the balanced panel database. The study is an improvement over the earlier studies in that it considers very recent time series data which is not done in the previous studies and there is a dearth of literature that focuses on the interstate variation in respect of estimated efficiency scores for different years.

### Selection of Sample States

The study encompasses 18 major states of India, three of which were bi-

furcated in November 2000. The bifurcated states are: Bihar, Madhya Pradesh and Uttar Pradesh. Three new states, viz., Jharkhand, Chattisgarh and Uttarakhand were carved out of Bihar, Madhya Pradesh and Uttar Pradesh, respectively. To ensure the comparability of pre-bifurcation period with the post-bifurcation period, the data for the newly created state has been merged into the respective state from which it was created. Thus, the states included in this study, arranged in alphabetical order are: Andhra Pradesh (AP), Bihar (BIH), Delhi (DEL), Gujarat (GUJ), Haryana (HAR), Karnataka (KAR), Kerala (KER), Maharashtra (MAH), Madhya Pradesh (MP), Orissa (ORI), Punjab (PUN), Rajasthan (RAJ), Tamil Nadu (TN), Uttar Pradesh (UP) and West Bengal (WB).

**Database & Variables**

The required data have been collected from various issues of Annual Survey of Industries (ASI) compiled by Central Statistical Organization (CSO), Government of India and Economic & Political Weekly Research Foundations (EPWRF) electronic database. A concordance between NIC 1998 and NIC 1987 at two-digit level has been made to build a comparable and continuous time series database. Suitable price indices deflators have been constructed with the help of the official series on wholesale price indices (Index Numbers of Wholesale Prices in India, prepared by the Office of the Economic Advisor; Ministry of Industry). The standard practice of perpetual inventory method has been followed to generate the

series of gross fixed capital stock at constant prices. The price indices of machinery and equipment were used to deflate nominal fixed capital as provided by ASI. The figures of total persons engaged provided by Annual Survey of Industries consists of both non production and production workers, and has been used as the measure of labor input. Gross output has been taken as output.

**Model Specification**

Following Aigner, Lovell and Schmidt (1977) the time varying translog production function for two inputs can be specified in the following form. Inclusion of a trend variable *t* with interaction terms allows us to identify the contribution of technological change to TFP growth. A notable advantage of the stochastic frontier is the fact that the restrictive assumptions about firms operating with full efficiency are relaxed.

$$\ln Y_{it} = \beta_0 + \beta_1 \ln L_{it} + \beta_k \ln K_{it} + \beta_{ll} (\ln L_{it})^2 + \beta_{kk} (\ln K_{it})^2 + \beta_{tt} t^2 + \beta_{lk} (\ln L_{it})(\ln K_{it}) + \beta_{tl} (\ln L_{it})t + \beta_{tk} (\ln K_{it})t + v_{it} - u_{it} \dots \dots \dots (1)$$

Where  $Y_{it}$  is the gross value of output; *K* and *L* are the inputs for capital and labor respectively and  $i=1,2,\dots,N$ ;  $t=1,2,\dots,T$ ;  $j k=L,K$ . *N* is the number of states included in the analysis. *T* is the number of time periods in the data series. *K* is the number of inputs considered. The efficiency error  $u_{it}$  represents production loss due to industry specific technical inefficiency; thus, it is always greater than or equal to zero ( $u_{it} > 0$ ). It is assumed to be independent of statistical error  $v_{it}$  which is assumed to be

independently and distributed as  $N(0, \sigma_v^2)$ .

Following Battese and Coelli (1992) the distribution of technical inefficiency effects,  $u_{it}$  taken to be non-negative truncation of the normal distribution  $N(\alpha, \sigma_u^2)$  and modeled to be the product of an exponential function of time as

$$u_{it} = \eta_i u_i = \exp[-\eta(t-T)] u_i, i=1, 2, \dots, N; t=1, 2, \dots, T \dots \dots \dots (2)$$

Here, the unknown parameter  $\eta$  represents the rate of change in technical inefficiency and the non-negative random variable,  $u_i$ , is the technical inefficiency effect for the  $i^{th}$  firm in the last year for the dataset. A firm with positive  $\eta$  is likely to improve its level of efficiency over time and vice-versa. A value of  $\eta = 0$  implies no time effect.

Technical efficiency of unit  $i$  at time  $t$  ( $TE_{it}$ ) is defined as the ratio of the actual output to the potential output as

$$TE_{it} = \exp(-u_{it}) \dots \dots \dots (3)$$

TEC is the change in TE.

$$\begin{aligned} \epsilon_k &= \frac{\partial \ln Y}{\partial \ln K} \\ &= \beta_k + 2\beta_{kk} \ln K + \beta_{kl} \ln L \\ &+ \beta_{kt} t \dots \dots \dots \end{aligned}$$

$$\begin{aligned} \epsilon_L &= \frac{\partial \ln Y}{\partial \ln L} = \beta_l + 2\beta_{ll} \ln L + \beta_{kl} \ln K \\ &+ \beta_{lt} t \dots \dots \dots \end{aligned}$$

Differentiating equation (1) with respect to K and L we have the respective output elasticities as follows.

The output elasticities of input K and L are

The equations indicate the percentage change in output due to 1% change in inputs. The sum of two elasticities is used to obtain returns to scale. The elasticity of scale measures how output varies as a particular input bundle is augmented by a scalar.

**Tests of Hypotheses**

Before commenting on the parameter estimates of the stochastic frontier production function and inefficiency effects model, various specification tests of the parameters have been performed in the frontier function using the generalized likelihood ratio (LR) test statistic.

The Generalized likelihood ratio (LR) statistics,  $\eta$ , is given by

$$\eta = -2 \ln \{L(H_0)\} - \ln \{L(H_1)\} \dots \dots \dots (6)$$

Where  $L(H_0)$  is the value of log likelihood function under null hypothesis. The test statistic  $\eta$  has approximately a mixed chi-square distribution with degree of freedom equal to the difference between the number of parameters estimated under  $H_0$  and  $H_1$  respectively. Testing for the validity of the translog over Cobb- Douglas specification using LR test statistic shows the rejection of the null hypoth-

**Translog specification is preferred to the Cobb-Douglas representation.**

esis implying translog specification is preferred to the Cobb-Douglas representation. The second null hypothesis that there is no technical change is strongly rejected by the data in all cases. Thus, given that the technology can be described by a stochastic translog frontier, the individual states cannot be sup-

posed to be all technically efficient. The third null hypothesis is that technical progress is neutral. It is to be noted that parameterization of the stochastic frontier model allows for non-neutral technical progress. The fourth null hypothesis, specifying that technical inefficiency effects have half normal distribution ( $H_0 = \mu = 0$ ) against truncated normal distribution, is rejected at 1% significance level. The last null hypothesis that technical inefficiency is time invariant ( $H_0 = \eta = 0$ ) is rejected.

**Table1 Generalized Likelihood-ratio Tests of Null Hypotheses for Parameters Values in the Estimated Stochastic Frontier Production Function**

Null Hypothesis	Estimated LR Test Statistic	D.f.	Critical value		Decision
			1%	5%	
$H_0 = \beta_u = \beta_{kk} = \beta_{tt} = \beta_{kk} = \beta_{tt} = \beta_{kk} = 0$ (Cobb-Douglas Production function)	29.22	6	16.81	12.59	Reject
$H_0 = \beta_i = \beta_{ik} = \beta_{it} = \beta_{it} = 0$ (No Technical Change)	109.48	4	13.2	89.49	Reject
$H_0 = \beta_{kt} = \beta_{kt} = 0$ (Neutral Technical Progress)	13.36	2	9.21	5.99	Reject
$H_0 = \lambda = 0$ (Technical inefficiency effects have half normal distribution)	10.68	1	6.63	3.84	Reject
$H_0 = \eta = 0$ Time invariant Technical inefficiency)	23.5	1	6.63	3.84	Reject

Note: The critical value for the test is taken from Table 3 of Kodde and Palm (1986:1246)

**Maximum Likelihood Estimates**

The maximum likelihood estimates of the parameters of the translog frontier production function model and the technical inefficiency effects model defined by equations (1) and (2) are reported in Table 2 using the computer package FRONTIER 4.1 (Coelli, 1996).

The signs of the estimated parameters of the translog production model are significant at conventional levels in most

of the cases. The estimate of  $\gamma$  which is the ratio of variance of industry specific performance of technical efficiency to total variance of output is statistically significant at 1% level in aggregate manufacturing sector across states in India. All the estimates of  $\eta$  are positive. A significantly positive value of  $\beta_{kt}$  indicates technical change is capital using and negative value of  $\beta_{lt}$  indicates technical change is labor saving. Technical change is neutral if all  $\beta_{ij}$  are equal to zero.

**Table 2 Panel Estimation of Stochastic Production Frontier & Technical Efficiency Model**

Variable		Coefficient	t-statistics
Constant	$\beta_o$	-11.36*	1.58
ln L	$\beta_l$	3.52***	7.45
ln K	$\beta_k$	-1.46***	-3.20
T	$\beta_t$	0.219***	3.66
(lnL) <sup>2</sup>	$\beta_{ll}$	-0.170***	-4.78
(lnK) <sup>2</sup>	$\beta_{kk}$	-0.528*	-1.96
t <sup>2</sup>	$\beta_{tt}$	-0.00091*	-1.54
(ln L. lnK)	$\beta_{lk}$	0.191***	3.18
(ln L) *t	$\beta_{lt}$	-0.028***	-3.78
(ln K) *t	$\beta_{kt}$	0.0220***	3.54
$\sigma$		0.039***	4.24
$\gamma$		0.611***	6.97
$\mu$		0.308***	4.18
$\eta$		0.0317***	3.66
Log Likelihood function		177.86	

Source: Authors' own calculation based on ASI data

Note: 1) The dependent variable for frontier estimation is  $\ln y_{it}$ . Total number of observations is 304.

2) The values in column (4) show t-statistics

3) \*, \*\*, \*\*\* show 10%, 5%, and 1% level of significance respectively.

**Table 3 Estimates of Output Elasticity**

States	$E_k$	$E_L$	RTS
Andhra Pradesh	0.312	0.481	0.793
Assam	0.128	0.804	0.932
Bihar	0.056	0.934	0.990
Orissa	0.037	0.970	1.007
West Bengal	0.265	0.564	0.829
Haryana	0.186	0.705	0.891
Punjab	0.249	0.591	0.840
Delhi	0.141	0.780	0.921
Gujarat	0.183	0.714	0.897
Madhya Pradesh	0.141	0.785	0.926
Maharashtra	0.224	0.641	0.866
Rajasthan	0.146	0.776	0.922
Karnataka	0.205	0.673	0.877
Kerala	0.250	0.587	0.838
Uttar Pradesh	0.212	0.660	0.872
Tamil Nadu	0.320	0.469	0.788
Average	0.191	0.703	0.887

Note:  $E_k$ ,  $E_L$ , RTS denotes elasticity of capital, elasticity of labor, returns to scale respectively.

Source: Author's own calculation based on ASI data

**For all Indian industries, the average across the state for output elasticity of capital over the years is 0.191 while that for labor is 0.703.**

Table 3 provides the mean estimates of both capital ( $E_K$ ) and labor elasticity ( $E_L$ ) for each state as calculated using equation (4) & (5). For all Indian industries, the average across the state for output elasticity of capital over the years is 0.191 while that for labor is 0.703.

**Returns to scale (RTS) for Indian industries is 0.887, implying that Indian manufacturing sector is characterized by decreasing returns to scale.**

Adding elasticity of capital and labor together, the resulting returns to scale (RTS) for Indian industries is 0.887, implying that Indian manufacturing sector is characterized by decreasing returns to scale. The production technology exhibits decreasing returns to scale in almost all states except Orissa. The state with highest labor elasticity is Orissa and Bihar and the lowest is Tamil Nadu followed by Andhra Pradesh. Conversely, the states, namely, Andhra Pradesh and Tamil Nadu have the highest value for capital elasticity and the lowest for Orissa and Bihar.

#### Analysis of Efficiency Scores

Table 4 displays mean technical efficiency estimates for each state and its

**Increasing technical efficiency scores over the years indicate that states have moved closer to the production frontier over time.**

rank over the entire study period starting with 1993 to 2011. The state, Gujarat has the highest mean technical efficiency across the entire time period and Assam is the least efficient state. Mean technical efficiency for the Indian industrial sector estimates over the period from 1993 to 2011 is estimated to be 0.663. It is remarkable to note that there is an increasing trend of technical efficiency across the states. Increasing technical efficiency scores over the years indicate that states have moved closer to the production frontier over time.

#### Conclusion & Policy Implications

Based on the results it is recognized that aggregate manufacturing sector across states in India has performed well in terms of efficiency though the efficiency scores are mixed in nature over the reference period. For future development, productive efficiency and technical change in industries have been prominent issues in discussions on the regional diversity of output and employment growth in the industrial sector in a developing country like India. Government should take necessary action to improve productive efficiency of the industries across states. Once efficiency increases, it enhances competitiveness by realizing the potential output. Non-improvement of technical efficiency over

Table 4 Year wise Technical Efficiency Level Estimates by State

States	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Andhra Pradesh	0.440	0.451	0.463	0.474	0.485	0.496	0.507	0.518	0.529	0.539	
Assam	0.367	0.379	0.390	0.402	0.413	0.425	0.436	0.448	0.459	0.471	
Bihar	0.572	0.582	0.592	0.602	0.612	0.621	0.630	0.639	0.648	0.657	
Orissa	0.454	0.465	0.476	0.488	0.499	0.510	0.520	0.531	0.542	0.552	
West Bengal	0.435	0.446	0.458	0.469	0.480	0.491	0.502	0.513	0.524	0.535	
Haryana	0.686	0.694	0.702	0.710	0.717	0.725	0.732	0.739	0.746	0.753	
Punjab	0.521	0.532	0.542	0.553	0.563	0.573	0.583	0.593	0.603	0.613	
Delhi	0.572	0.582	0.592	0.601	0.611	0.620	0.630	0.639	0.648	0.657	
Gujarat	0.947	0.948	0.950	0.951	0.953	0.954	0.956	0.957	0.958	0.959	
Madhya Pradesh	0.680	0.689	0.697	0.705	0.712	0.720	0.727	0.735	0.742	0.749	
Maharashtra	0.914	0.917	0.919	0.922	0.924	0.926	0.929	0.931	0.933	0.935	
Rajasthan	0.573	0.583	0.593	0.603	0.612	0.622	0.631	0.640	0.649	0.658	
Karnataka	0.540	0.550	0.561	0.571	0.581	0.591	0.601	0.610	0.620	0.629	
Kerala	0.421	0.432	0.444	0.455	0.466	0.477	0.489	0.500	0.511	0.521	
Uttar Pradesh	0.631	0.640	0.649	0.657	0.666	0.675	0.683	0.691	0.699	0.707	
TamilNadu	0.553	0.564	0.574	0.584	0.594	0.604	0.613	0.623	0.632	0.641	
Average	0.582	0.591	0.600	0.609	0.618	0.627	0.636	0.644	0.653	0.661	
<b>States</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>Mean</b>	<b>Rank</b>
Andhra Pradesh	0.550	0.560	0.570	0.581	0.590	0.600	0.610	0.619	0.629	0.543	14
Assam	0.482	0.493	0.504	0.515	0.526	0.536	0.547	0.557	0.567	0.475	16
Bihar	0.666	0.674	0.683	0.691	0.699	0.707	0.715	0.722	0.729	0.660	7
Orissa	0.562	0.573	0.583	0.593	0.602	0.612	0.621	0.631	0.640	0.556	12
West Bengal	0.545	0.556	0.566	0.576	0.586	0.596	0.606	0.615	0.625	0.538	13
Haryana	0.760	0.766	0.773	0.779	0.785	0.791	0.797	0.802	0.808	0.754	3

Punjab	0.622	0.631	0.640	0.649	0.658	0.667	0.675	0.684	0.692	0.615	11
Delhi	0.665	0.674	0.682	0.690	0.698	0.706	0.714	0.722	0.729	0.659	8
Gujarat	0.961	0.962	0.963	0.964	0.965	0.966	0.967	0.968	0.969	0.960	1
Madhya Pradesh	0.755	0.762	0.769	0.775	0.781	0.787	0.793	0.799	0.804	0.750	4
Maharashtra	0.937	0.939	0.941	0.942	0.944	0.946	0.947	0.949	0.951	0.935	2
Rajasthan	0.667	0.675	0.683	0.691	0.700	0.707	0.715	0.723	0.730	0.660	6
Karnataka	0.638	0.647	0.656	0.665	0.673	0.682	0.690	0.698	0.706	0.632	10
Kerala	0.532	0.543	0.553	0.564	0.574	0.584	0.594	0.603	0.613	0.525	15
Uttar Pradesh	0.715	0.722	0.730	0.737	0.744	0.751	0.758	0.764	0.771	0.709	5
Tamil Nadu	0.650	0.659	0.667	0.676	0.684	0.692	0.700	0.708	0.716	0.643	9
Average	0.669	0.677	0.685	0.693	0.701	0.708	0.716	0.723	0.730	0.663	

Source: Author's Own Calculation based on ASI data

the years is one area of concern the government should look into. Direction of technical change is another area firms should concentrate on.

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