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ASSESSING THE OUTPUT AND PRODUCTIVITY GROWTH OF INDIAN MANUFACTURING INDUSTRIES DURING THE POST REFORM PERIOD: EVIDENCE FROM STOCHASTIC FRONTIER APPROACH

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Abstract: Applying the stochastic frontier production function approach, this paper estimates and decomposes the output growth as well as total factor productivity (TFP) of aggregate manufacturing industries across states in India during 1993-2011. The result indicates that change in inputs and TFP play more important roles for output growth while the contribution of capital input is negative. It is remarkable to note that most of the states have achieved negative change in input growth in the years 1998, 2000, and 2001, respectively. However, of all the factors responsible for the output growth, change in input growth contributes the most, followed by technological progress and technical efficiency, respectively. Though technical efficiency is a component of TFP growth, it contributes little to TFP growth and thus the improvement of technical efficiency is the key element for improving the efficiency of Indian manufacturing sector. Technical progress being larger than technical efficiency to the TFP growth in most of the states for the Indian manufacturing sector. The estimated technical efficiency scores across the states have increased over the years, implying that the states gradually move closer to the production frontier over time.

Keywords: Indian manufacturing, Total factor productivity, Technical efficiency, Technological progress, Stochastic frontier

1. Introduction

Accumulation of production factors and productivity growth are among the major determinants of economic growth. Due to the scarceness of available resources, it is essential to consider other approaches for economic growth, especially efficiency and total factor productivity (TFP). Productivity is a comprehensive concept and refers to the effective and efficient use of resources

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to obtain the highest and best output (Hejazi et al., 2008). Solow (1957) emphasized the role of technical change towards shifting of a production function. Productivity growth is recognized as a key feature of economic dynamism today. In the last two decades, the productivity growth measurement literature has been extended from the standard calculations of TFP employing production function framework to more refined decomposition methods.

Output growth over time is usually attributed to growth in inputs and improvements in total factor productivity. While measuring the sources of output growth, the contribution of TFP is always estimated as a residual, after accounting for the growth of inputs. Operation on the production frontier implies that improvement in productivity arises from technological progress (TP) and industries can achieve improvement following the best practice method of application of technology, commonly regarded as technical efficiency (TE). Stochastic frontier models assume that firms do not fully utilize existing technology because of various non-price and organizational factors that lead to inevitable technical inefficiencies in production. Under these circumstances, TFP growth may arise from improvements in technical efficiency (TE), without technical progress (TP).

From a policy perspective, researchers acknowledge that the decomposition of TFP into efficiency changes and technical changes provides useful information in productivity. Policymakers can recommend policies that are more effective in improving the productivity of firms if they understand the sources of variation in productivity growth. For example, if low productivity growth results from slow TP, then a policy to induce technological innovation should be recommended to shift up the production frontier. If high rates of TP coexist with deteriorating TE, resulting in slow productivity growth, then a policy to increase the efficiency is required, which might include improvements in learning-by-doing processes and in managerial practices.

Nishimizu and Page (1982) first proposed the decomposition of TFP into efficiency changes and technical changes. Later, researchers have applied their approach in various studies in order to investigate productivity growth. Coelli et al. (2005) provide an introduction to the four principal methods involved such as econometric estimation of average response models, index numbers, data envelopment analysis (DEA), and stochastic frontier analysis (SFA) in his famous book. However, Aigner et al. (1977) and Meeusen and van den Broeck (1977) simultaneously proposed a stochastic frontier production model that shows TFP growth has two sources: technological progress (TP) and change in technical efficiency (TEC). The former reflects the improvement stemming from innovation and the diffusion of new knowledge and technologies, while the latter measures the movement of production towards the frontier. A notable advantage of the stochastic frontier approach is that the restrictive assumptions about firms operating with full efficiency are relaxed. Studies that assume that firms operate with full efficiency ignore the potential contribution of efficiency changes to TFP growth, which leads to biased and misleading results. The stochastic frontier model has been intensively used to decompose TFP growth at the firm, industry, state, and even more at the national levels.

At the very outset, the present study estimates total factor productivity growth in aggregate manufacturing sector during the period from 1994-95 to 2010-11, using panel data and applying stochastic frontier approach. The study is an improvement over the earlier studies with respect to the fact that it considers very recent time series data which has not been used in other studies. We have got a detailed panel data set of aggregate manufacturing industries across fifteen states from 1993 to 2011. An attempt has been made to decompose output growth in Indian manufacturing industries into input growth, technical progress and technical efficiency components. Estimating TFP growth with frontier approach helps to examine the role of technical progress as well as technical efficiency change and input growth component in TFP growth.

This paper is structured as follows. A brief literature of review is presented in section 2. Section 3 presents a decomposition of TFP and also presents the functional form of the model to be estimated. Section 4 discusses the data and measurement of variables. Section 5 highlights empirical findings. Section 6 concludes the paper and draws policy prescriptions.

2. Brief Review of Literature

A vast number of empirical applications have contributed to identify the source of TFP growth by focusing on its decompositions. By applying a flexible stochastic translog production function, Kumbhakar and Lovell (2000), Kim and Han (2001) and Sharma et al. (2007) decompose TFP growth into four components: technological progress, changes in technical efficiency, changes in allocative efficiency and scale effects. Mitra et al. (1998) estimated state level performance of total factor productivity and technical efficiency from the estimation of production functions for 17 manufacturing industries from 1976 to 1992. The study highlighted that differences across states in total factor productivity and technical efficiency of manufacturing sector are mainly due to the differences in infrastructure endowments. The article by Farrell (1957) provided a satisfactory measure of productive efficiency. Mahadevan (2001, 2002) used both stochastic frontier approach and DEA separately to calculate the TFPG of Malaysian manufacturing industries during 1981-1996. He used the same data set to make comparison between the two approaches and concluded that both the methods demonstrated a decline of TFPG after 1990, increasing contribution of technology progress and declining contribution of technical efficiency change. Another study by Raj and Natarajan (2008) examined the technical efficiency in the unorganized manufacturing sector of Kerala and depicted the existence of high level of technical inefficiency due to which their potential level has reduced significantly. The study by Roy et al. (2015) applies a stochastic frontier production approach to decompose the sources of TFPG of the total organized manufacturing industries in fifteen major industrialized states in India during the period from 1981-1982 to 2010-2011, According to the estimated results, technological progress (TP) is the main contributor to the TFPG of the organized manufacturing from 1981-1982 to 2010-2011. Kumar and Managi (2009) have tried to analyze regional variations in terms of productivity growth during 1993-2005. The study found that although there exists interstate variations in productivity growth at the all India level, a tendency of convergence is found in the states that are efficient. Kumar (2004) endeavoured to analyse regional variations in technical efficiency of Indian manufacturing sector using the method of stochastic frontier approach. The results revealed wide variations in the technical efficiency of manufacturing sectors of different states. The highest level of technical efficiency has been observed in the manufacturing sector of Maharashtra. Mukherjee and Ray (2004) analyzed the state level data of the manufacturing sector of India for the period from 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) have 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. Kim et al. (2009) measured the technical efficiency for different groups of firms of Malaysian economy with the help of stochastic frontier production model. The empirical findings indicated that during 2000-2004 technical efficiency across all industries decelerated while technical progress was observed across all the industries as well as firm sizes. Bhandari and Maiti (2012) attempt to estimate technical efficiency of individual leather producing firms for some years by applying two conventional methods viz. data envelope analysis and stochastic frontier approach. The findings of the study imply significant variations in technical efficiency across firms in different groups of states as well as under different organisational structures.

In contrast, the present study concentrates on estimation of TFP growth with frontier approach and attempts to identify the relative role of technical progress as well as technical efficiency change and input growth components in TFP growth.

3. Decomposition and Model Specification

3.1 Decomposition of TFP

The decomposition of TFP can be introduced in the production function. Aigner et al. (1977) and Meeusen and Van den Broeck (1977) independently proposed the stochastic frontier production function defined as follows:

$$y_{it} = f\left(x_{it}, \beta, t\right)\exp\left(v_{it}\right)\exp\left(-u_{it}\right) \quad (1)$$

where y_{it} is the maximum possible output produced by ith firm ($i=1,2,....,N$) in t^{th} period ($t=1,2,....,T$) with $f(x_{it}, \beta, t)$ being the production frontier, x_{it} being the input vectors, β being the vector of technology parameters, t being time trend that serves as proxy for technical change, $u_{it} > 0$ is the output oriented technical inefficiency. The random error $v_{it} \gtrless 0$ accounts for measurement error. It is assumed that the usual error term v_i is i.i.d $N^{+}(0,\sigma_{v2})$ while the inefficiency term u_i is i.i.d $N^{+}(\mu_i,\sigma_u^{\ 2})$ where μ is the mean before truncation. Further, these two random terms are assumed to be independent of each other as well as of the regressors.

The production frontier f(.) is totally differentiated with respect to time to get

$$\frac{d\ln f\left(x_{it},\beta,t\right)}{dt} = \frac{\partial \ln f\left(x_{it},\beta,t\right)}{\partial t} + \sum_j \frac{\partial \ln f\left(x_{it},t\right)}{\partial x_j}\frac{dx_j}{dt} \quad (2)$$

The first and second terms on the right-hand side of equation (2) measure the change in frontier output caused by technical progress (*TP*) and by change in input use, respectively. By definition, the output elasticity of input j, $\varepsilon_j = \frac{\partial \ln f\left(x_{it},\beta,t\right)}{\partial \ln x_j}$. The second term can be expressed as $\sum_j \varepsilon_j \dot{x}_j$, where a dot over a variable indicates its rate of change.

Thus, equation (2) can be written as

$$\frac{d\ln f\left(x_{it},\beta,t\right)}{dt} = TP + \sum_j \varepsilon_j \dot{x}_j \quad (3)$$

Totally differentiating the logarithm of y in equation (1) with respect to time and using equation (3) the change in production can be expressed as

$$\dot{y}_{it} = \frac{d\ln f\left(x_{it},\beta,t\right)}{dt} - \frac{du}{dt} = TP + \sum_j \varepsilon_j \dot{x}_j - \frac{du}{dt} \quad (4)$$

The overall productivity change is not only affected by *TP* and changes in input use, but also by changes in technical inefficiency. The overall productivity change is not only affected by *TP* and changes in input use, but also by changes in technical inefficiency. TP is positive (negative) if exogenous technical change shifts the production frontier upward (downward) for a given level of inputs. If $\frac{du}{dt}$ is negative (positive), TE improves (deteriorates) over time and -- $\frac{du}{dt}$ can be interpreted as the rate at which an inefficient producer catches up to the production frontier.

3.2 Model Specification

Following Aigner et al. (1977), the time varying translog production function for two inputs can be specified in the following form. We include a trend variable t with interaction terms that allows us to identify the contribution of technological change to TFP growth.

$$\ln Y_{it} = \beta_0 + \beta_l \ln L_{it} + \beta_k \ln K_{it} + \beta_t t + \beta_{ll} (\ln L_{it})^2 + \beta_{kk} (\ln K_{it})^2$$
$$+ \beta_{tt} t^2 + \beta_{lk} (\ln L_{it}) (\ln K_{it}) + \beta_{lt} (\ln L_{it}) t + \beta_{kt} (\ln K_{it}) t + v_{it} - u_{it} \quad (5)$$

where Y_{it} is the gross value of output; K and L are the inputs for capital and labour, respectively, and $i = 1,2,......,N$; $t=1,2,.... ,T$; $j,k=L,K$. 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 distributed as $N(0,\sigma_v^2)$.

Following Battese and Coelli (1995), the distribution of technical inefficiency effects, u_{it}, is taken to be non-negative truncation of the normal distribution $N(\mu,\sigma_u^2)$ and modelled to be the product of an exponential function of time as

$$u_{it} = \eta_i u_i = \exp\left[-\eta\left(t - T\right)\right] u_i,\ i = 1,2,\ldots,N;\ t = 1,2,\ldots,T \quad (6)$$

Here, the unknown parameter η 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 η 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 (i.e. TE_{it}) is defined as the ratio of the actual output to the potential output as

$$TE_{it} = \exp(-u_{it}) \quad (7)$$

TEC is the change in TE. The elasticity of output with respect to the jth input is defined by

$$\xi_j = \partial \ln f(x,t) \big/ \partial \ln x_j = \alpha_j + \sum_{i \neq j} \beta_{jt} \ln \chi_i + \beta_{jj} \ln \chi_j + \beta_{Tj} t \quad \text{j, i=L,K} \quad (8)$$

The rate of TP is defined by

$$TP = \partial \ln f(x,t) / \partial t = \alpha_T + \beta_{TT}\, t + \beta_{tl}\ (\ln L) + \beta_{kl} (\ln K) \quad (9)$$

In the estimations of equations (8) and (9), output elasticity and TP are functions of input levels.

4. Data and Measures of Variables

The data used in this paper are a balanced panel consisting of annual time-series data of aggregate manufacturing industries across fifteen states in India from 1993 to 2011. The study encompasses 18 major states of India, three of which were bifurcated in November 2000. The bifurcated states are: Bihar, Madhya Pradesh and Uttar Pradesh. Three new states, *viz.*, Jharkhand, Chhattisgarh 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, we have added the data for the newly created states to the respective states from which they were created. Thus, the states included in this study are: Andhra Pradesh, Assam, Bihar, Orissa, West Bengal, Haryana, Punjab, Delhi, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Kerala, Uttar Pradesh and Tamil Nadu. The required dataset for the present study has been collected from the Annual Survey of Industries (ASI) compiled by the Central Statistical Organisation (CSO), Government of India.

Gross output / value of output has been used as the proxy for output; and this has been converted into real terms by deflating it by the wholesale price index (WPI) for the respective industries. Suitable deflators for gross output and capital are taken from Index Number of Wholesale Prices in India, prepared by the Office of the Economic Advisor, Ministry of Industry, Government of India.

Gross fixed capital stock (at the 1993-94 constant prices) is taken as the measure of capital input. Total persons engaged / total employees have been used as a measure of labour input. We have selected fourteen major two-digit level industry groups following the NIC 1987 code (National Industrial Classification code). A concordance between NIC 1998 and NIC 1987 two-digit level industry groups has been made to build a comparable and continuous time series at the two-digit level NIC 1987 classification. 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 price indices of machinery and equipment were used to deflate nominal fixed capital as provided by ASI.

5. Empirical Findings

This section presents the results of the estimations of the stochastic production function parameters, testing of hypotheses, estimation of elasticities with respect to inputs, and finally decomposition of TFP growth in Indian manufacturing industries. The discussions start with the estimation of stochastic production frontier.

5.1 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 (5) and (6) are reported in Table 1 using the computer software package FRONTIER 4.1 (see Coelli, 1996).

The fitted translog frontier production function satisfies two properties, namely monotonicity (non-negative elasticity of output with respect to each input) and quasi-concavity (which indicates that the Boarder-Hessian determinant of first and second derivatives is negative semi-definite), for majority of observations. The signs of the estimated parameters of the translog production model are significant at conventional levels in most of the cases. The estimate of γ 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 η are positive. A significantly positive value of β_{kt} indicates that technical change is biased towards more use of capital and negative value of β_{lt} indicates that technical change favours the usages of less labour. Technical change is neutral if all β_{tj}'s are equal to zero.

5.2 Hypotheses Tests

A number of statistical tests of hypotheses for the production frontier model parameters are carried out and Table 2 presents the test results of various null hypotheses on the total number of observations. The null hypotheses are tested using likelihood ratio tests. The likelihood ratio test statistic is

$$\lambda = -2\left[\ln\left\{L\left(H_o\right)\right\} - \ln\left\{L\left(H_1\right)\right\}\right] \quad (10)$$

Table 1: Panel Estimation of Stochastic Production Frontier and Technical Efficiency Model

Variable	Coefficient	Value of coefficient	t-statistic	Standard error
Constant	β_o	-11.36*	-7.19	1.58000
ln L	β_l	3.52***	7.45	0.47248
ln K	β_k	-1.46***	-3.20	0.45625
T	β_t	0.219***	3.66	0.05984
$(\ln L)^2$	β_{ll}	-0.170***	-4.78	0.03556
$(\ln K)^2$	β_{kk}	-0.528*	-1.96	0.26939
t^2	β_{tt}	-0.00091*	-1.54	0.00059
(ln L. lnK)	β_{lk}	0.191***	3.18	0.06006
(ln L) *t	β_{lt}	-0.028***	-3.78	0.00741
(ln K) *t	β_{kt}	0.0220***	3.54	0.00621
σ^2		0.039***	4.24	0.00920
γ		0.611***	6.97	0.08766
μ		0.308***	4.18	0.07368
η		0.0317***	3.66	0.00866
Log Likelihood function		177.86		

Notes: i) The dependent variable for frontier estimation is $\ln Y_{it}$ and total number of observations is 304; ii) *, **, *** show 10%, 5%, and 1% levels of significance, respectively.
Source: Author's calculation based on ASI data

where $L(H_0)$ and $L(H_1)$ are the values of log likelihood function under the specifications of the null and alternative hypotheses, H_0 and H_1, respectively.

If null hypothesis is true, then λ has approximately a mixed chi-square distribution (or a mixed chi-square) with degree of freedom equal to the number of restrictions. If the null hypothesis includes $\eta = 0$ then the asymptotic distribution is a mixed chi-square distribution (Coelli and Battese, 1996).

The first null hypothesis that the technology in Indian manufacturing is a Cobb-Douglas ($H_0 = \beta_u = \beta_{kk} = \beta_{tt} = \beta_{lk} = \beta_{tl} = \beta_{tk} = 0$) is rejected for the total observations. Thus, the Cobb-Douglas production function is not an adequate specification for the Indian manufacturing sector given the assumptions of the translog stochastic frontier production model. The second null hypothesis that there is no technical change ($H_0 = \beta_t = \beta_{tk} = \beta_{tl} = \beta_{tt} = 0$) and the third null hypothesis that technical progress is neutral ($H_0 = \beta_{tk} = \beta_{tl} = 0$) are both rejected at the 1% significance level for the aggregate manufacturing industries across states in India. 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 also rejected. Given these results, our specification of full translog model with time-varying technical inefficiency appears to appropriately represent the production technology for the aggregate manufacturing industries across states.

Table 3 provides the mean estimates of both capital elasticity (E_K) and labour elasticity (E_L) for each state as calculated using equation (8). For all Indian industries, the average across the state for output elasticity of capital over the years is 0.191 while that for labour is 0.703.

Table 2: Generalised Likelihood-ratio Tests for Parameters of Estimated Stochastic Frontier Production Function

Null hypothesis	Estimated LR test statistic	D.f.	Critical value		Decision
			1%	5%	
$H_0 = \beta_{ll} = \beta_{kk} = \beta_{tt} = \beta_{lk} = \beta_{lt} = \beta_{kt} = 0$ (Cobb-Douglas production function)	29.22	6	16.81	12.59	Reject
$H_0 = \beta_t = \beta_{kt} = \beta_{lt} = \beta_{tt} = 0$ (No technical change)	109.48	4	13.28	9.49	Reject
$H_0 = \beta_{kt} = \beta_{lt} = 0$ (Neutral technical progress)	13.36	2	9.21	5.99	Reject
$H_0 = \mu = 0$ (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, p.1286)

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

Table 3: Estimates of Output Elasticities of Capital (E_K) and Labour (E_L)

States	E_K	E_L	Returns to Scale
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 and E_L denote elasticity of capital and elasticity of labour, respectively.
Source: Author's calculation based on ASI data

5.3 Analysis of Efficiency Scores

Table 4 displays mean technical efficiency estimates for each state and its rank over the entire study period from 1993 to 2011. The maximum likelihood estimation of equations (5) and (6) provides the parameter estimates of frontier function as well as the efficiency estimates. Gujarat state 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.

5.4 Decomposition Result

Decomposition of output growth and total factor productivity growth of the individual states for each year is reported in Table 5. The output growth of a specific state can be expressed as the sum of input growth and total factor productivity growth (TFPG). Again, TFPG can be expressed as the sum of growth of technological progress (TP), and technical efficiency change (TEC). So, the present analysis attempts to decompose output growth of a specific state into input growth and TFPG which can be further decomposed into growth of TP and change in TEC. The estimates of TEC are calculated on the basis of estimated efficiency scores as reported in Table 4. Consequently, changes in input growth and TP are derived by using the equations (2) and (9), respectively. Then the output growth (OUTG) of a specific state in a particular year is obtained by summing the changes in input growth, TEC and TP using the equation (4). Using equation (4) along with parameter estimates, the output growth rates have been decomposed into growth of TP, change in TEC as well as change in input growth (ING). In addition, total factor productivity growth has been obtained by summing up growth of TP and change in TEC. The TFP index is used to construct a grand frontier based on the data from all the states which have been considered in the present study. A state is said to be technically efficient if it gets much closer to the grand frontier, and a shift of grand frontier to a state's observed input mix is called technical change. Change in technical efficiency can make use of existing input to produce greater quantity of same product. As one earns more experience in producing some product, it becomes more and more efficient in that activity. Total factor productivity (TFP) is usually measured as the ratio of aggregate output index to aggregate input index. The aggregate input quantities are weighted by input shares to develop the input indices. Before constructing output and input indices the quantities are shifted to a common base year. Then the rate of TFP growth is calculated by subtracting growth rates of labour and capital inputs from the growth rate of output. Again, it is to be noted that the benchmark value for TFP index is 100. So, the result that we usually obtain always exceeds 100, which supports our calculation. That is why the sum of the components by which TFP is decomposed is not equal to 100.

West Bengal state witnessed lowest output growth in the year 1998 and Orissa achieved highest in the year 2010. The input growth is the largest component of output growth. If we look at TP column in Table 5, we see that aggregate manufacturing industries have realized positive growth rates during the entire study period. TP is the major contributing factor to TFP growth for the Indian manufacturing sector. The highest technological progress is attained by Orissa with a growth rate of 9.25%. Although technological progress has shown an improvement over the years, it is offset by low rate of technical efficiency change as reflected in TEC column in Table 5 (observe each year). Technological progress is closely related to research and development (R&D) activities and industry upgrading policies.

Examining the contribution of TEC to TFP growth, it is noteworthy that almost all states witness positive growth of technical efficiency over the period. A positive growth rate of technical efficiency indicates a movement towards the production frontier, which also means an increase in output growth. Declining technical efficiency reveals that inputs have not been used effectively in these industries. Actually, we have concentrated on Table 4 to present an analysis of each state as well as interstate comparison among the states, considering a benchmark state achieving the highest score. The estimates of technical efficiency for almost all states have shown an increase

Table 4: Technical Efficiency Level Estimates by Industry and Year

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
Tamil Nadu	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

States	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean Efficiency	Rank
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 calculation based on ASI data

Table 5: Decomposition of Total Factor Productivity Growth, 1994-2011 (in Percent)

	1994				1995				1996			
	TFP				TFP				TFP			
States	**ING**	**TP**	**TEC**	**OUTG**	**ING**	**TP**	**TEC**	**OUTG**	**ING**	**TP**	**TEC**	**OUTG**
Andhra Pradesh	19.98	2.05	1.14	23.18	7.03	1.75	1.13	9.92	-2.87	2.54	1.13	0.79
Assam	11.88	3.3	1.17	16.34	18.53	3.92	1.17	23.61	-8.18	3.58	1.16	-3.44
Bihar	1.11	5.66	1.01	7.78	-1.48	5.89	0.99	5.41	-2.14	6.08	0.98	4.92
Orissa	3.17	5.98	1.13	10.28	0.35	6.52	1.13	8.00	-9.55	7.45	1.12	-0.99
West Bengal	4.53	3.09	0.81	8.43	9.3	3.08	0.8	13.18	-0.17	3.7	0.78	4.3
Haryana	7.43	3.81	1.15	12.39	11.56	4.22	1.14	16.92	3.12	4.68	1.13	8.93
Punjab	4.87	3.19	1.07	9.12	10.81	3.81	1.06	15.68	4.08	4.08	1.05	9.2
Delhi	16.73	4.69	1.01	22.43	-3.68	4.73	0.99	2.05	-3.2	4.94	0.98	2.72
Gujarat	6.41	3.91	0.16	10.48	26.88	5.39	0.16	32.43	-0.48	5.41	0.15	-4.92
Madhya Pradesh	5.99	4.61	0.82	11.42	14.79	4.89	0.81	20.48	-6.59	5.07	0.79	-0.72
Maharashtra	10.77	4.34	0.25	15.36	17.69	4.43	0.25	22.37	-2.77	5.02	0.24	2.49
Rajasthan	11.56	5.08	1	17.65	7.67	5.16	0.99	13.82	4.52	5.44	0.98	10.93
Karnataka	10.08	3.46	1.05	14.59	11.34	3.86	1.04	16.23	14.46	4.32	1.02	19.8
Kerala	13.02	2.18	1.15	16.35	1.44	3.6	1.15	6.18	-2.87	2.99	1.14	1.26
Uttar Pradesh	4.76	4.4	0.91	10.07	4.26	4.42	0.9	9.58	5.56	4.88	0.88	11.32
Tamil Nadu	15.62	3	1.03	19.66	7.76	3.06	1.02	11.83	4.61	3.41	1	9.03

	1997				1998				1999			
	TFP				TFP				TFP			
States	**ING**	**TP**	**TEC**	**OUTG**	**ING**	**TP**	**TEC**	**OUTG**	**ING**	**TP**	**TEC**	**OUTG**
Andhra Pradesh	19.43	2.92	1.12	23.47	-22.92	3.38	1.11	-18.43	6.67	3.48	1.1	11.25
Assam	15.51	4.98	1.16	21.65	-31.52	4.58	1.16	-25.79	2.49	4.81	1.15	8.45
Bihar	-17.29	6.31	0.96	-10.02	-151.9	6.97	0.95	-144	7.16	6.85	0.93	14.95
Orissa	-2.23	6.95	1.11	5.82	-23.6	6.8	1.1	-15.7	-7.28	6.74	1.08	0.54
West Bengal	6.09	3.52	0.76	10.38	-56.86	0.91	0.75	-55.2	15.42	3.42	0.73	19.58
Haryana	-5.08	5.19	1.12	1.23	14.55	4.83	1.11	20.49	-17.62	5.91	1.1	-10.6
Punjab	-2.38	4.5	1.03	3.14	-35.01	4.04	1.02	-29.95	8.69	4.5	1	14.2
Delhi	-20.1	4.87	0.96	-14.26	-8.76	4.93	0.95	-2.89	6.59	4.93	0.93	12.45
Gujarat	5.79	6.01	0.15	11.95	-4.93	6.44	0.14	1.65	1.16	6.41	0.14	7.71
Madhya Pradesh	-3.76	4.97	0.77	1.99	-38.63	5.78	0.76	-32.09	-10.09	6.11	0.74	-3.24
Maharashtra	2.6	5.2	0.23	8.03	-0.34	5.8	0.23	5.68	-8.17	6.45	0.22	-1.5
Rajasthan	-3.7	5.86	0.96	3.12	-20.12	5.93	0.95	-13.25	-0.32	7.21	0.93	7.82
Karnataka	11.52	4.99	1.01	17.52	-5.77	6.13	0.99	1.36	-12.79	5.94	0.98	-5.88
Kerala	15.12	4.01	1.13	20.26	-20.52	4.06	1.12	-15.34	6.35	4.04	1.12	11.51
Uttar Pradesh	-2.16	5.44	0.87	4.15	-16.84	6.42	0.85	-9.57	-9.38	6.05	0.83	-2.5
Tamil Nadu	4.27	3.51	0.99	8.77	-5.71	4	0.97	-0.73	2.2	4.27	0.96	7.42

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	2000				2001				2002			
	TFP				TFP				TFP			
States	ING.	TP	TEC	OUTG	ING	TP	TEC	OUTG	ING	TP	TEC	OUTG
Andhra Pradesh	-0.19	3.40	1.09	4.30	4.45	3.73	1.07	9.25	9.68	3.59	1.06	14.34
Assam	1.37	6.35	1.14	8.87	-4.61	5.50	1.14	2.03	2.98	6.44	1.13	10.55
Bihar	-7.91	7.02	0.91	0.01	-0.58	7.10	0.90	7.42	-17.59	8.04	0.88	-8.67
Orissa	-2.62	7.20	1.07	5.66	-10.99	7.54	1.06	-2.40	2.02	7.29	1.05	10.35
West Bengal	-0.96	3.50	0.72	3.26	7.37	4.54	0.70	12.62	0.57	4.61	0.68	5.86
Haryana	1.44	5.96	1.09	8.49	-3.19	6.12	1.08	4.02	4.19	6.04	1.07	11.30
Punjab	1.14	3.98	0.99	6.11	-0.83	4.06	0.98	4.20	7.01	4.63	0.96	12.60
Delhi	-7.90	5.27	0.92	-1.71	-1.18	5.30	0.90	5.02	7.82	5.25	0.88	13.96
Gujarat	-6.42	6.76	0.13	0.47	-2.59	7.21	0.13	4.75	0.76	7.15	0.13	8.03
Madhya Pradesh	-6.12	5.84	0.72	0.45	-16.77	6.30	0.71	-9.76	1.03	6.45	0.69	8.17
Maharashtra	-2.16	6.57	0.21	4.63	-0.56	6.51	0.21	6.16	2.59	6.66	0.20	9.45
Rajasthan	-3.13	6.45	0.91	4.23	0.36	6.48	0.90	7.74	4.62	6.30	0.88	11.80
Karnataka	-3.14	5.90	0.96	3.72	4.47	6.08	0.95	11.50	1.12	6.20	0.93	8.26
Kerala	3.91	4.05	1.10	9.07	-0.15	4.20	1.09	5.15	-7.89	4.47	1.08	-2.34
Uttar Pradesh	-5.29	5.99	0.82	1.52	-5.25	5.84	0.80	1.38	4.21	5.63	0.78	10.62
Tamil Nadu	2.18	4.14	0.94	7.26	-2.09	4.14	0.93	2.98	7.22	4.42	0.91	12.56

	2003				2004				2005			
	TFP				TFP				TFP			
States	ING	TP	TEC	OUTG	ING	TP	TEC	OUTG	ING	TP	TEC	OUTG
Andhra Pradesh	-4.39	1.05	1.05	-2.3	5.41	4.01	1.04	10.46	5.19	4.02	1.02	10.22
Assam	3.56	1.12	1.12	5.8	4.54	6.42	1.11	12.07	6.78	6.23	1.1	14.11
Bihar	6.19	0.87	0.87	7.93	7.36	7.4	0.85	15.62	8.23	7.02	0.83	16.08
Orissa	6.33	1.03	1.03	8.4	14.55	7.49	1.02	23.05	0.85	8.14	1.01	9.99
West Bengal	-1.71	0.67	0.67	-0.38	1.29	4.72	0.65	6.66	2.07	4.82	0.64	7.53
Haryana	6.32	1.06	1.06	8.43	9.32	5.79	1.04	16.15	9.09	5.55	1.03	15.67
Punjab	-4.51	0.94	0.94	-2.62	11.87	4.23	0.93	17.03	12.01	4.23	0.91	17.16
Delhi	-8.64	0.87	0.87	-6.91	4.62	5.29	0.85	10.76	4.93	5.15	0.84	10.92
Gujarat	2.44	0.12	0.12	2.69	7.9	6.83	0.12	14.84	11.01	6.94	0.12	18.07
Madhya Pradesh	2.72	0.68	0.68	4.08	3.25	6.7	0.66	10.61	1.43	6.75	0.65	8.83
Maharashtra	-2.51	0.2	0.2	-2.12	4.29	6.77	0.19	11.25	4.88	6.52	0.19	11.59
Rajasthan	1.32	0.87	0.87	3.06	7.65	6.11	0.85	14.61	7.22	5.95	0.83	14
Karnataka	4.88	0.92	0.92	6.71	7.33	6	0.9	14.23	11.63	5.68	0.88	18.2
Kerala	10.95	1.07	1.07	13.1	1.73	4.09	1.06	6.88	4.22	3.91	1.05	9.18
Uttar Pradesh	5.13	0.77	0.77	6.67	3.18	5.51	0.75	9.45	9.17	5.41	0.74	15.32
Tamil Nadu	4.67	0.9	0.9	6.46	6.73	4.29	0.88	11.91	7.36	4.28	0.86	12.51

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	2006				2007				2008			
	TFP				TFP				TFP			
States	**ING**	**TP**	**TEC**	**OUTG**	**ING**	**TP**	**TEC**	**TFP**	**ING**	**TP**	**TEC**	**OUTG**
Andhra Pradesh	8.81	4.27	1.01	14.09	7.31	4.44	0.99	12.75	6.5	4.46	0.98	11.94
Assam	5.63	6.1	1.09	12.82	-0.23	6.19	1.08	7.04	8.55	5.9	1.07	15.51
Bihar	-0.74	6.93	0.82	7.01	7.94	6.52	0.8	15.26	-0.05	6.43	0.79	7.16
Orissa	12.45	8.11	0.99	21.55	14.6	8.29	0.98	23.87	14.89	8.2	0.96	24.06
West Bengal	0.79	4.86	0.62	6.27	3.86	4.98	0.61	9.45	9.42	5.12	0.6	15.14
Haryana	7.66	5.51	1.02	14.18	14.43	5.23	1	20.66	14.69	5.01	0.99	20.69
Punjab	13.69	4.16	0.9	18.75	7.62	4.08	0.88	12.58	4.83	4.35	0.86	10.05
Delhi	1.95	5.1	0.82	7.87	-1.43	5.02	0.8	4.39	0.05	5.01	0.79	5.85
Gujarat	8.57	6.72	0.11	15.4	5.22	6.57	0.11	11.9	7.74	6.53	0.11	14.37
Madhya Pradesh	8.08	6.6	0.63	15.31	7.03	6.47	0.62	14.12	7.17	6.42	0.6	14.19
Maharashtra	9.87	6.31	0.18	16.37	-1.18	6.39	0.17	5.38	8.64	6.25	0.17	15.06
Rajasthan	5.76	5.96	0.82	12.54	14.72	5.54	0.8	21.06	3.41	6.23	0.79	10.43
Karnataka	8.7	5.5	0.87	15.07	4.15	5.6	0.85	10.61	11.24	5.9	0.84	17.98
Kerala	3.35	3.9	1.03	8.28	2.56	3.78	1.02	7.36	9.29	3.87	1	14.17
Uttar Pradesh	7.42	5.38	0.72	13.52	9.19	5.43	0.71	15.32	0.84	5.51	0.69	7.04
Tamil Nadu	17.72	3.57	0.85	22.13	-6.48	4.13	0.83	-1.52	10.89	3.97	0.82	15.67

	2009				2010				2011			
	TFP				TFP				TFP			
States	**ING**	**TP**	**TEC**	**OUTG**	**ING**	**TP**	**TEC**	**OUTG**	**ING**	**TP**	**TEC**	**OUTG**
Andhra Pradesh	19.65	5.37	0.96	25.98	13.26	5.29	0.95	19.50	16.56	5.90	0.93	23.39
Assam	1.45	5.98	1.05	8.49	9.76	5.76	1.04	16.55	11.82	5.98	1.03	18.82
Bihar	17.11	6.33	0.77	24.22	16.29	5.89	0.75	22.93	17.15	5.76	0.74	23.65
Orissa	11.08	9.00	0.94	21.02	22.41	8.81	0.93	32.15	3.99	9.25	0.91	14.15
West Bengal	12.46	5.64	0.58	18.69	5.94	5.29	0.57	11.80	7.42	5.48	0.55	13.46
Haryana	1.93	5.29	0.97	8.19	2.26	5.81	0.96	9.03	5.40	5.67	0.94	12.01
Punjab	3.87	4.26	0.85	8.98	11.24	4.39	0.83	16.47	2.74	4.57	0.82	8.13
Delhi	0.35	5.36	0.77	6.48	2.71	5.43	0.75	8.89	5.01	6.29	0.74	12.04
Gujarat	9.62	6.95	0.10	16.68	9.68	6.78	0.10	16.56	7.35	6.75	0.10	14.19
Madhya Pradesh	4.19	6.50	0.59	11.28	14.99	6.81	0.57	22.37	2.85	6.85	0.56	10.26
Maharashtra	4.03	6.34	0.16	10.53	10.52	6.22	0.16	16.89	7.40	6.00	0.15	13.56
Rajasthan	10.73	6.13	0.77	17.62	11.92	6.23	0.75	18.90	7.26	6.00	0.74	13.99
Karnataka	11.46	5.68	0.82	17.96	-3.51	6.19	0.80	3.48	12.81	6.01	0.79	19.60
Kerala	1.20	4.09	0.99	6.28	7.27	4.20	0.97	12.44	2.69	4.09	0.96	7.74
Uttar Pradesh	5.56	5.58	0.67	11.82	5.84	5.50	0.66	12.01	8.38	5.53	0.64	14.56
Tamil Nadu	13.97	4.29	0.80	19.06	5.58	4.35	0.78	10.71	3.98	4.45	0.77	9.20

Source: Author's calculation based on ASI data over the years, but the interstate comparison on the basis of mean technical efficiency score shows that the performances of some states such as Andhra Pradesh, Assam and Kerala are not satisfactory in comparison to the benchmark states (i.e. Gujarat and Maharashtra that achieved first and second positions, respectively). These states have a departure from the grand frontier, implying their incapability to produce the maximum outputs by using the same level of inputs.

The contribution due to change in input growth is reported in ING (input growth) column of Table 5. The states, namely Andhra Pradesh, Assam, Bihar, Orissa, West Bengal, Delhi, Madhya Pradesh, Maharashtra, and Kerala witness negative input growth in the year 1996. The negative growth of an input (say, labour) indicates that an increase in labour input causes output to fall. This is possible if any input is used beyond its optimal level, then its contribution is bound to fall following the law of diminishing returns. A second possibility may arise if the producer (a state) chooses capital intensive technology which results in negative growth of labour inputs. This induces a shrink in employment opportunities. Alternatively, more effective utilization of inputs like labour and capital by a state rather than adoption of technological innovation surely points out the input growth as the highest contributing factor relative to the other components of output growth. The column indicating output growth (OUTG) in Table 5 presents the estimated output growth rates across states during the period of 1994-2011. Input growth is the major contributing component of TFP growth. It is remarkable to note that most of the states have achieved negative input growth in the years 1998, 2000, and 2001, respectively. The analysis of the state-wise estimates of total factor productivity growth shows that there is a positive trend of TFP growth during the period from 1994-95 to 1995-96. In the year 1994-95, the states having the highest contribution of change in input growth to TFP growth are Andhra Pradesh (20%), Delhi (16.7%), Tamil Nadu (15%), Kerala (13%), Rajasthan (12%), and Assam (12%). In the year 1998, almost all the states have experienced negative output growth and the main contributing factor behind it is the changes in input growth.

6. Conclusions and Policy Implications

This study has provided an overall evaluation of the output growth in Indian manufacturing sector, using decomposition method. Decomposing the TFP growth into technological progress and efficiency changes is important to better understand whether gains in industrial productivity levels are achieved through the efficient use of inputs or through technological progress. Ranking Indian states in terms of efficiency shows that Gujarat has the highest mean technical efficiency across the entire time period and Assam is the least efficient state. The production technology exhibits decreasing returns to scale in almost all states except Orissa. The states with higher labour elasticity are Orissa and Bihar, respectively, and the state with lowest labour elasticity is Tamil Nadu, followed by Andhra Pradesh. Examining the contribution of technical efficiency change to TFP growth, it is noteworthy that almost all states enjoy positive growth rate of technical efficiency over the period.

Policy actions needed to improve TFP growth rate might be misdirected if the focus is given on accelerating the rate of innovation in circumstances where the low rate of TFP growth is taking place due to suboptimal size of the industries and low rate of technology diffusion (technical inefficiency), which really happened in the case of Indian manufacturing sector. The manufacturing sector of the Indian states needs greater investments in R&D activities and adoption of new technology in order to improve the present condition. Human resource development, especially skill improvement of workers, reduces skill deficiencies which often tend to inhibit technological adoption. Thus, this should be seriously taken into consideration. Again, improvement of technical efficiency requires improvement in quality of inputs such as capital and labour. The government should take necessary measures to improve productive efficiency of the industries across states.

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