

Productivity Growth of Indian Manufacturing: Panel Estimation of Stochastic Production Frontier

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Along with technological progress, changes in technical efficiency, scale effect and changes in allocative efficiency can also contribute to productivity growth. The present study used the stochastic frontier production approach to decompose sources of TFPG of organized manufacturing into technological progress, changes in technical efficiency, scale effect and changes in allocative efficiency during 1981/82 -2010/11. According to the results, technical inefficiency, though exists, is time invariant and technological progress (TP) became the main contributor to TFPG of the sector during 1981/82 – 2010/11. Furthermore, TFPG of organized manufacturing in most states in India declined during the post-reform period due to the decline in technological progress.

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Introduction

Most of the studies relating to productivity growth in Indian manufacturing considered technological progress to be the unique source of total factor productivity growth (TFPG) and it can be shown by the shift in production possibility frontier over time. However, some recent studies (Aigner, Lovell & Schmidt, 1977; Meeusen & Van den Broeck, 1977) have used a stochastic frontier production model that allows decomposing TFPG into two components: technological progress (TP) and change in technical efficiency (TE). Later, studies by, among others, Nishimizu and Page (1982), Kumbhakar (1990), Fecher and Perelman (1992), Domazlicky and Weber (1998) have been focusing on decomposition of TFPG using Stochastic Frontier Approach. Some studies have extended their analyses to

deal with the issues of scale effect and allocative efficiency effect. By applying a flexible stochastic translog production function, Kumbhakar and Lovell (2000), Kim and Han (2001) and Sharma et al (2007) decomposed TFPG into four components: changes in technological progress, changes in technical efficiency, economic scale effect and changes in allocative efficiency.

In the present study we have used the stochastic production frontier approach to decompose TFPG of the total organized manufacturing industries in India and fifteen major industrialized states assuming that manufacturing industries in the states are not able to fully utilize the existing resources and technology because of various non-price and organizational factors that might have led to technical inefficiencies in production. Using panel data of the organized manufacturing industries of the states as well as all-India over a period from 1981-82 to 2010-11, pre-reform period (1981-82 to 1990-91), post-reform-period (1991-92 to 2010-11) and also during the two decades in the post-reform period (1991-92 to 2000-01 and 2001-02 to 2010-11), we have decomposed TFPG of the organized manufacturing sector into technological progress, changes in technical efficiency, scale effect and allocative efficiency effect. This decomposition of TFPG of Indian manufacturing has also been made for the pre-and post reform periods, and also for different decades in order to examine the trend and variations in the TFPG and its different components, during these sub-periods.

Decomposition of TFPG

Stochastic frontier model was first developed by Aigner, Lovell and Schmidt (1977) and Meeusem Van den Broeck (1977) and it was later extended by Pit and Lee (1981), Schmidt and Sickles (1984), Kumbhakar (1990) and Battese and Coelli (1992) to allow for panel data regression estimation in which technical efficiency and technological progress vary over time and across different production units. Here we discuss the methodology used in the efficiency literature for estimating stochastic production frontier and the decomposition of TFPG. We start with a standard stochastic frontier model that can be estimated using panel data. The model is written as:

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

where y_{it} represents the output of the i -th production unit ($i=1 \dots N$) at time t ($t=1 \dots T$); $f(\cdot)$ denotes the production frontier of the i -th production unit at time ' t '; X_{it} is the input vector used by the i -th production unit at time ' t '; β is the vector of technology parameter; ' t ' is the time trend serving as a proxy for technological change; V_{it} 's are symmetric random error terms independently and identically distributed with mean zero, and variance σ_v^2 , used to capture random variations in output due to external shocks like weather, strikes, lock-out etc. u_{it} 's are non-negative random variables associated with technical inefficiency of production, which are assumed to be independently distributed, such that u_{it} 's are obtained by truncation at zero of the nor-

mal distribution with mean \bar{u} and variance σ_u^2 .

Taking logs of equation (1) and totally differentiating it with respect to time give the growth rates of output at time 't' for the i-th production unit as shown below:

$$\dot{y}_{it} = d \ln f(x_{it}, \beta, t) / dt - du_{it} / dt = \partial \ln f(x_{it}, \beta, t) / \partial t + \sum_j \partial \ln f(x_{it}, \beta, t) / \partial x_{jt} \cdot dx_{jt} / dt - du_{it} / dt \quad (2)$$

The first and second terms on the right-hand side of equation (2) measure the change in frontier output caused by technological progress (TP) and change in input use respectively. From the formula of output elasticity of input 'j', $\partial \ln f(x_{it}, \beta, t) / \partial \ln x_{jt}$, the second term can be expressed as $\sum_j \epsilon_j \dot{x}_{jt}$, where a dot over a variable indicates its rate of change. Thus, equation (2) can be written as

$$\dot{y}_{it} = TP_{it} + \sum_j \epsilon_j \dot{x}_{jt} - du_{it} / dt \quad (3)$$

The overall productivity change is not only affected by TP and changes in input use, but also by changes in technical inefficiency.

Thus, the overall productivity change is not only affected by TP and changes in input use, but also by changes in technical inefficiency. TP will be positive if the exogenous change in technology shifts the production frontier upward and it will be negative if it shifts the production frontier downward. On the other hand, if du_{it} / dt is negative, TE improves and if du_{it} / dt is positive, TE deteriorates over time; and $-du_{it} / dt$ can be interpreted as the rate at

which an inefficient producer catches up with the production frontier.

To examine the effect of TP and a change in efficiency on TFPG, let us express TFPG as output growth unexplained by input growth:

$$TFP_{it} = \dot{y}_{it} - \sum_j S_j \dot{x}_{jt} \quad (4)$$

where S_j denotes the observed expenditure share of input 'j'.

By substituting equation (3) into equation (4), we get

$$TFP_{it} = TP_{it} - du_{it} / dt + \sum_j (\epsilon_j - S_j) \dot{x}_{jt} = TP_{it} - du_{it} / dt + (\epsilon - 1) \sum_j \lambda_j \dot{x}_{jt} + \sum_j (\lambda_j - S_j) \dot{x}_{jt} \quad (5)$$

where $\epsilon = \sum_j \epsilon_j$ denotes the measurement of returns to scale (RTS) and $\lambda_j = \epsilon_j / \epsilon$. The last component in equation (5) measures inefficiency in resource allocation resulting from the deviation of input prices from the value of their marginal products. Thus, in equation (5), TFP growth is decomposed into: i) TP that measures the shift in production frontier over time; ii) technical efficiency change ($-du_{it} / dt$) that measures the shift in production towards the known production frontier; iii) effect of scale change [$(\epsilon - 1) \sum_j \lambda_j \dot{x}_{jt}$] which shows the amount of benefit a production unit can derive from economies of scale through access to a larger market and iv) the allocative efficiency change denoted by $\sum_j (\lambda_j - S_j) \dot{x}_{jt}$. This last component captures the impact of deviations of inputs' normalized output elasticities from their

expenditure shares (Kumbhakar & Lovell, 2000).

Model Specification

In our empirical analysis, we opt for a parametric approach by considering the time varying stochastic production frontier, originally proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), in translog form as

$$\ln y_{it} = \beta_0 + \sum_j \beta_j \ln x_{jit} + \beta_t t + 1/2 \sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + 1/2 \beta_{tt} t^2 + \sum_j \beta_{tj} t \ln x_{jit} + v_{it} - u_{it}; j, k=L, K \text{-----(6)}$$

In equation (6), y_{it} is the observed output, 't' is the time variable and 'x' variables are inputs, subscripts j and k index of inputs. The efficiency error, u_{it} , accounting for production loss due to unit-specific technical inefficiency, is always greater than or equal to zero and assumed to be independent of the random error; v_{it} , the random error which is assumed to have the usual properties ($\sim iidN(0, \sigma^2_v)$).

The translog production frontier as specified in equation (6) is rewritten for two inputs - labor (L) and capital (K) in the following form:

$$\ln y_{it} = \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_t t + 1/2 \beta_{LL} L_{it}^2 + 1/2 \beta_{KK} K_{it}^2 + 1/2 \beta_{tt} t^2 + \beta_{LK} \ln L_{it} \ln K_{it} + \beta_{Lt} L_{it} t + \beta_{Kt} K_{it} t + v_{it} - u_{it} \text{----- (7)}$$

where y_{it} , L_{it} and K_{it} are respectively the value added, labor input, and capital input for the aggregate manufacturing industry in state 'i' at time 't'; The distribution of technical inefficiency effects,

u_{it} is taken to be non-negative truncation of the normal distribution $N(\mu, \sigma_u^2)$, following Battese & Coelli (1992), to take the form as

$$u_{it} = \eta_t u_i = u_i \exp(-\eta[t-T]), i=1, \dots, N; t=1, \dots, T \text{-----(8)}$$

The technical inefficiency effects in earlier periods are a deterministic exponential function of the inefficiency effects for the corresponding forms in the final period.

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} production unit in the last year for the data set. That is, the technical inefficiency effects in earlier periods are a deterministic exponential function of the inefficiency effects for the corresponding forms in the final period, (i.e., $u_{it}=u_i$) given that data for the i^{th} production unit are available in period T. So the manufacturing industry with a positive η is likely to improve its level of efficiency over time and vice-versa. A value of $\eta=0$ implies no time effect.

Since the estimates of technical efficiency are sensitive to the choice of distributional assumption, we consider truncated normal for general specifications for one-sided error u_{it} , and a half-normal distribution can be tested by Likelihood Ratio (LR) test.

Given the estimates of the parameters in equations (7) and (8), the techni-

cal efficiency level of unit 'i' at time 't' (TE_{it}), defined as the ratio of the actual output to the potential output, determined by the production frontier, can be written as

$$TE_{it} = \exp(-u_{it}) \quad (9)$$

and TEC is the change in TE, and the rate of technological progress (TP_{it}) is defined by,

$$TP_{it} = \frac{\partial \ln f(x_{it}, \beta, t)}{\partial t} = \beta_t + \beta_{tt} t + \beta_{Lt} \ln L_{it} + \beta_{kt} \ln K_{it} \quad (10)$$

where β_t and β_{tt} are 'Hicksian' parameters and β_{Lt} and β_{kt} are 'factor augmented' parameters. It is noted that when technological progress is non-neutral, the change in TP may be varied for different input vectors. To avoid such problems, Coeli et al (1998: 234) suggest that the geometric mean between the adjacent periods be used to estimate the TP component. The geometric mean between time 't' and t+1 is defined as:

$$TP_{it} = \frac{[1 + \frac{\partial \ln f(x_{it}, \beta, t)}{\partial t}] * [1 + \frac{\partial \ln f(x_{it+1}, \beta, t+1)}{\partial t+1}]^{1/2} - 1}{1} \quad (11)$$

Both TE_{it} and TP_{it} vary over time and across the production units.

The associated output elasticities of inputs labor and capital can be defined as

$$\epsilon_L = \frac{\partial \ln f(x_{it}, \beta, t)}{\partial \ln L_{it}} = \beta_L + \beta_{LL} \ln L_{it} + \beta_{LK} \ln K_{it} + \beta_{Lt} t \quad (12)$$

$$\epsilon_K = \frac{\partial \ln f(x_{it}, \beta, t)}{\partial \ln K_{it}} = \beta_K + \beta_{KL} \ln L_{it} + \beta_{KK} \ln K_{it} + \beta_{Kt} t \quad (13)$$

The above equations show the percentage change in output due to one percent change in inputs. They are used to estimate the aggregate returns to scale (ϵ). The scale elasticity of output, i.e. the change in output with respect to change in scale, is given by the formula:

$$\epsilon = \epsilon_L + \epsilon_K \quad (14)$$

If scale elasticity exceeds unity, then the technology exhibits increasing returns to scale (IRS), if it is equal to one, the technology obeys constant returns to scale (CRS), and if it is less than unity, the technology shows decreasing returns to scale (DRS).

Data Sources

The data used in this study are the panel data of aggregate manufacturing industries of fifteen major industrialized states in India, namely, Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal and all-India during the period from 1980-81 to 2010-11. The panel data are prepared from the data on output and inputs collected from the various issues of Annual Survey of Industries (ASI), published by Central Statistics Office (Industrial Statistics Wing), Kolkata, Ministry of Statistics and Program Implementation, Government of India, the National Accounts Statistics published by the Central Statistical Organization, Ministry of Statistics and Program Implementation, Govt. of India, and Handbook of Statistics on the Indian Economy published by

Reserve Bank of India. The variables used in this study are output, labor and capital inputs. To make the values of output and capital comparable over time and across the states and all India, suitable deflators have been used. The definitions of the variables, the deflators used and various issues involved in the selection of these variables are presented below.

Output

In our study, we have used gross value added (GVA) as the measure of output. Gross output is not taken here as a measure of output in order to avoid the possibility of double counting. Productivity estimation in our study assumes output to be a function of labor and capital only. It is, therefore, appropriate to take value added as a representative of output instead of the value of output itself. However, net value added might have been a better measure of output, but since the depreciation figures are not reliable as the entrepreneurs often provide us with inflated figures in order to avoid taxes, we have preferred gross value added to net value added as a measure of output.

If value added is used as a measure of output, nominal output needs to be converted into real output either by single deflation or by double deflation. In the case of single deflation, nominal value added is deflated by the output price index, which means that both nominal output and nominal inputs are deflated by the same output price index whereas in the case of double deflation nominal output is deflated by the output price index

and the nominal inputs by the input price index. If both output and input prices change in the same proportion, then the ratio of input-output prices remains same and in such a situation, the estimation of the growth of output and productivity by single deflation and double deflation will give the same result. We have used single deflation method instead of double deflation since in our study the materials inputs and fuels have been left out of the consideration due to non-availability of input price data, particularly at the state level. The real value added is obtained here by deflating nominal value added by Wholesale Price Index (WPI) for the manufacturing products.

Labor

In our study, we have taken total number of persons engaged as labor input. Further, as workers, supervisors, managers, storekeepers, office bearers, all working proprietors, and their family members who are actively engaged in the works in the factories even without any pay, have significant contributions to the productivity, total number of persons engaged is preferred to all other measures as labor input. Total emoluments divided by total number of persons engaged in production is considered as price of labor input in our study.

Capital

The measurement of capital is the most complex of all input measurements. In many studies, capital is treated as a stock concept and is, therefore, measured by the book value of fixed capital assets. Some

studies have used the perpetual inventory accumulation method (PIAM) to construct capital stock series from annual investment data. In this study, we also used the PIAM to obtain the fixed capital stock series. Goldsmith (1957) was the first to introduce the PIAM in the literature.

Rental price of capital that equals the ratio of interest paid to capital invested (Jorgenson & Griliches, 1967) is assumed to be price of capital in our study.

Empirical Results

The estimation of parameters in the stochastic frontier model given by equations (9) and (10) are carried out by maximum-likelihood (ML) method, using the program FRONTIER 4.1 (Coelli, 1996). Instead of directly estimating σ_v^2 and σ_u^2 , FRONTIER 4.1 seeks to estimate $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$, the results of which are presented in Table 2. These are associated with the variances of the stochastic term in the production function, v_{it} and the inefficiency term u_{it} . The parameter γ must lie between zero and one. If the hypothesis $\gamma=0$ is accepted, this would indicate that σ_u^2 is zero and thus the efficiency error term, u_{it} should be removed from the model, leaving a specification with parameters that can be consistently estimated by OLS. Conversely, if the value of γ is one, we have the full-frontier model, where the stochastic term is not present in the model.

Hypotheses Tests

We have performed a number of LR tests for the selection of proper functional

form and presence of inefficiency. We have examined various hypotheses which are tested by using the generalized likelihood ratio statistic, λ , given by

$$\lambda = -2[L(H_0) - L(H_1)]$$

where $L(H_0)$ and $L(H_1)$ denote the values of the log likelihood function under the null (H_0) and alternative (H_1) hypothesis respectively. If the given null hypothesis is true, λ has approximately a mixed chi-square (χ^2) distribution with degrees of freedom equal to the difference between the number of parameters under H_1 and H_0 respectively. Table 1 presents the test results of various null-hypotheses:

- 1) The first likelihood test is conducted to test the null hypothesis that the technology in the organized manufacturing sector in India is a Cobb-Douglas ($H_0: \beta_{LL} = \beta_{KK} = \beta_{LK} = \beta_{it} = \beta_{Lt} = \beta_{Kt} = 0$). This hypothesis is rejected. This is shown in Table 1 where a likelihood ratio of the value 61.35 indicates the rejection of null hypothesis even at 1% significance levels. Thus, Cobb-Douglas production function is not an adequate specification for the Indian manufacturing sector, given the assumption of the translog stochastic frontier production model, implying that the translog production better describes the technology of the Indian manufacturing.

Translog production better describes the technology of the Indian manufacturing.

Table 1 Hypothesis Test for Model Specification

Null Hypothesis	Test statistics $\bar{\epsilon} = -2[L(H_0) - L(H_1)]$	Critical value at 5% probability level	Critical value at 1% probability level	Decision
Cobb-Douglas Production Specification $H_0: \beta_{LL} = \beta_{KK} = \beta_{LK} = \beta_{it} = \beta_{Li} = \beta_{Ki} = 0$	61.35	12.59	16.81	Reject H_0
No technological change $H_0: \beta_{it} = \beta_{Li} = \beta_{Ki} = 0$	195.66	9.49	13.28	Reject H_0
Neutral technological change $H_0: \beta_{Li} = \beta_{Ki} = 0$	38.83	5.99	9.21	Reject H_0
No technical inefficiency effects $H_0: \gamma = \mu = \eta = 0$	271.99	7.81	11.34	Reject H_0
Half normal distribution $H_0: \mu = 0$	5.07	3.84	6.63	Reject H_0 at 5% level
Technical inefficiency is time-invariant, $H_0: \eta = 0$	0.65	3.84	6.63	Accept H_0
Technical inefficiency is time-invariant and follows half-normal, $H_0: \mu = \eta = 0$	5.91	5.99	9.21	Accept H_0

Source: Authors' own calculation

- 2) The second null hypothesis, that there is no technological change over time ($H_0: \beta_{it} = \beta_{Li} = \beta_{Ki} = 0$) is also strongly rejected. The value of the test statistic as shown in Table 1 is 195.66 which is significantly larger than the critical value of 13.28 at 1% probability level. This indicates the existence of technological change over time, given the specified production model.
- 3) The third null-hypothesis is that the technological change is Hicks neutral ($H_0: \beta_{Li} = \beta_{Ki} = 0$). The value of the test statistic in this case happens to be 38.83 which is much higher than the critical values of 9.21 at 1% probability level. This indicates that the translog parameterization of the stochastic frontier model does not allow for Hicks neutral technological change.
- 4) Fourth, null-hypothesis that technical inefficiency effects are absent

($H_0: \gamma = \mu = \eta = 0$) is rejected. This implies that the traditional production function which rules out the presence of technical inefficiency is not an adequate representation for the organized manufacturing industry in India. On the basis of our results, it can be said that inefficiencies are present in the Indian manufacturing industry and they are stochastic.

- 5) The fifth null-hypothesis, specifying that technical inefficiency effects have half-normal distribution ($H_0: \mu = 0$) against truncated normal distribution, is accepted at 5% level of significance though it is rejected at 1% significance level¹.
- 6) The sixth null-hypothesis, that technical inefficiency is time-invariant ($H_0: \eta = 0$) is accepted both at 5% and at 1% level of significance. This implies that technical inefficiency in the or-

1. The restriction of $\eta = 0$ reduces the model to model one in Pitt and Lee (1981).

ganized manufacturing industries in India is time-invariant².

Estimation of Stochastic Production function

The maximum likelihood estimates for the translog stochastic frontier production function are reported in Table 2. Almost all the estimated coefficients of

the translog stochastic frontier production function are found to be statistically significant at the conventional levels. However, under translog specification there may exist high level of multicollinearity due to the interaction and squared terms. This might have contributed to statistical insignificance of certain estimated coefficients (Table 2).

Table 2 Panel Estimation of Stochastic Production Frontier and Technical Efficiency Model

Variables	Parameters	Coefficients	Standard Errors	t-statistics
Constant	β_0	2.53	3.24	0.78
lnL	β_L	0.056	0.75	0.075
lnK	β_K	0.454	0.548	0.828
T	β_t	0.047*	0.031	1.50
lnL ²	β_{LL}	-0.032	0.06	-0.54
lnK ²	β_{KK}	-0.091***	0.034	-2.65
t ²	β_{tt}	-0.0012***	0.0002	-6.83
lnL*lnK	β_{LK}	0.138**	0.083	1.66
lnL*t	β_{Lt}	-0.021***	0.0044	-4.77
lnK*t	β_{Kt}	0.024***	0.0039	6.15
Sigma squared	σ^2	0.073***	0.010	7.28
Gamma	γ	0.70***	0.044	15.86
Mu	μ	0.45***	0.089	5.10
Eta	ϵ	-0.003	0.004	-0.80
	Log-Likelihood	214.04		

Source: Authors' own calculation

(*, **, *** denotes statically significant at the 10, 5 and 1 percent levels respectively)

In Table 2 the estimated value of γ is as high as 0.70 which implies that the organized manufacturing industries in India are operating at 70% of their potential output determined by the frontier technology. But statistical test suggests that technical efficiency of the organized manufacturing sector in India is time-invariant in nature, i.e., overtime changes in technical efficiency are not statistically

Statistical test suggests that technical efficiency of the organized manufacturing sector in India is time-invariant in nature.

significant in spite of moderate changes in technological progress taking place. It can be inferred, thus, that over the years innovating manufacturing industries are either continuing with or shifting for better technologies. For various reasons such as incomplete knowledge of the best

2. Time-invariant model of technology was set out in the literature by Battese, Coelly and Colby (1989)

practice and other organizational factors, they are unable to use the chosen technologies in the most efficient way. As a result, organized manufacturing sector in India fails to achieve 100% technical efficiency and the level of efficiency seems to be more or less at the same percentage (70%) level over the years.

Decomposition of TFPG

It has already been mentioned that TFPG of the organized manufacturing sector can be decomposed into four parts: changes in technological progress (TP), changes in technical efficiency (TE), economic scale effect (SC) and allocation efficiency effect (AE). However, technical efficiency of the sector is time-invariant, i.e., changes in technical efficiency during the study period are not statistically significant. Thus, in the absence

of technical efficiency change, TFPG of the sector in India as well as in the states is calculated as the sum of technical progress (TP), Scale change (SC) and allocative efficiency change (AEC). The main finding of the decomposition is that TP is the main contributor to the TFPG of the organized manufacturing industries in India as well as in major industrialized states. We present in Table 4 the significant results on the growth of TFPG and its three components such as TP, SC and AEC and also the contributions of these components to the TFPG of the organized manufacturing sector in different states in India and in all-India during the period from 1981-82 to 2010-11 and during different sub-periods such as during the pre-and post-reform period and during the two decades of post-reform period (1991-92 to 2000-01 and 2001-02 to 2010-11).

Table 3 Average Annual Growth Rate(%) of TFP and Its Components of the Organized Manufacturing Sector (1981-82 to 2010-11)

States	TP	SC	AEC	TFP
A.P.	4.08	-0.05	2.09	6.12
Assam	3.20	-0.23	1.44	4.14
Bihar	5.56	-0.05	1.61	7.11
Gujarat	5.74	-0.12	1.26	6.88
Haryana	4.20	-0.22	1.39	5.38
Karnataka	4.48	-0.14	1.88	6.22
Kerala	2.75	-0.01	0.83	3.58
M.P.	5.58	-0.15	0.94	6.37
Maharashtra	5.29	-0.02	1.14	6.42
Odisha	6.06	-0.47	1.69	7.28
Punjab	3.88	-0.12	0.52	4.28
Rajasthan	4.93	-0.21	0.75	5.48
Tamil Nadu	4.06	0.01	1.45	5.51
U.P.	5.03	0.01	0.47	5.51
W.B.	4.02	-0.07	1.61	5.57
India	5.57	0.12	0.79	6.48

Source: Authors' own calculation

Note TP=Technological Progress, AEC= Allocative Efficiency Change, SE= Economic Scale Effect, TFP=Total Factor Productivity

Table 3 shows that the states of Odisha and Kerala registered the highest and the lowest growth rate of TFP during 1981-82 to 2010-11. As many as 13 states including all-India registered higher than 5% average annual growth rate of TFP. The contribution of TP to TFPG was the highest among all the TFP components. The effect of scale change is found to be very insignificant, mostly negative whereas the contribution of AEC is satisfactory implying that the manufacturing industries in India have achieved allocative efficiency over the years. This is shown in Table 4.

The manufacturing industries in India have achieved allocative efficiency over the years.

The average annual growth rate of TFP has fallen from the pre-reform period to the post-reform period in as many as 12 states excepting three states, namely, Bihar, Karnataka and Odisha. TP is found to be the most important factor responsible for this decline in the 12 states-as well as rise in the three states in TFP during the post-reform period as compared to the pre-reform period (Table 4). AEC comes next in the order of the contributions of components to TFPG. Interestingly, AEC has made significant positive contribution to TFPG in all the states and in All India during the post-reform period compared to its contribution in the pre-reform period. This is a clear pointer to the fact that the registered manufacturing units have improved their allocative efficiency during the post-reform period so far as the

allocation of resources is concerned. The effect of scale change on TFPG has been negative in as many 9 out of 15 states during 1981-82 to 1990-91. In one state, namely, Kerala, its contribution was found to be zero. In the remaining 4 states, its contribution, though positive, was very low, ranging from 0.04 to 0.08 (0.04 in 3 states). Thus, in general, the effect of SC to TFPG was negligible in the pre-reform period.

In the post-reform period, the situation worsened further. Not only in as many as 12 out of 15 states its contribution was negative, but also in five states, negative contribution were higher than those in the pre-reform period. Interestingly, when TP declined in all the states, AEC made significant improvements in eight states as well as in India as a whole. Further, the results reveal that though during the second half of the post-reform period (2000-01 to 2010-11) TP declined in all the major industrialized states under study, AEC improved in eight states. The improvement in AEC in the post-reform period as compared to the pre-reform period and also in the second half of the post-reform period is the only brightening aspect of the industrial growth in India and its states. The positive role of the AEC has been largely responsible to counter the fall in TP in India and in many of its states. As regards the effect of scale change, its contribution has been very negligible throughout the period and also during different sub-periods. It can therefore be said that the organized manufacturing industries in India have not been benefitted from economies of scale.

Table 4 Average Annual Growth Rates (%) of TFP and Its Components in Organized Manufacturing Sector during 1981-82 to 1990-91 and 1991-92 to 2010-11

TIME PERIODS	STATES							
	A.P.	ASSAM	BIHAR	GUJ	HAR	KAR	KERA	M.P.
TP								
1981-82 to 1990-91 (Pre-reform period)	5.02	4.06	6.92	5.92	5.51	5.04	4.68	6.90
1991-92 to 2010-11 (Post-reform period)	3.62	2.78	4.88	5.65	3.55	4.20	1.79	4.92
SC								
1981-82 to 1990-91 (Pre-reform period)	-0.11	-0.04	0.08	0.04	-0.28	-0.06	0	-0.20
1991-92 to 2010-11 (Post-reform period)	-0.03	-0.33	-0.12	-0.20	-0.19	-0.18	-0.02	-0.12
AEC								
1981-82 to 1990-91 (Pre-reform period)	1.91	1.32	-0.22	0.99	0.37	0.84	0.56	0.03
1991-92 to 2010-11 (Post-reform period)	2.18	1.50	2.52	1.39	1.91	2.40	0.97	1.40
TFP								
1981-82 to 1990-91 (Pre-reform period)	6.82	5.33	6.78	6.94	5.60	5.82	5.24	6.73
1991-92 to 2010-11 (Post-reform period)	5.77	3.95	7.28	6.84	5.27	6.42	2.75	6.19
TIME PERIODS	STATES							
	MAHA	ODISHA	PUN	RAJ	T.N.	U.P.	W.B.	IND
TP								
1981-82 to 1990-91 (Pre-reform period)	6.07	6.71	5.75	6.37	5.11	5.96	4.81	6.51
1991-92 to 2010-11 (Post-reform period)	4.91	5.74	2.95	4.22	3.53	4.57	3.63	5.11
SC								
1981-82 to 1990-91 (Pre-reform period)	0.04	-0.23	-0.38	-0.24	-0.07	-0.02	0.04	0.01
1991-92 to 2010-11 (Post-reform period)	-0.04	-0.59	0.01	-0.19	0.05	0.02	-0.12	0.17
AEC								
1981-82 to 1990-91 (Pre-reform period)	0.80	0.59	0.15	0.26	1.12	-0.12	1.46	0.11
1991-92 to 2010-11 (Post-reform period)	1.31	2.23	0.71	1.00	1.61	0.76	1.68	1.13
TFP								
1981-82 to 1990-91 (Pre-reform period)	6.91	7.08	5.52	6.38	6.16	5.82	6.31	6.63
1991-92 to 2010-11 (Post-reform period)	6.17	7.38	3.67	5.03	5.19	5.35	5.19	6.41

Source: Authors' own calculation

Table 5 Average Annual Growth Rates (%) of TFP and Its Components in All-India and 15 Major Industrial States in India during 1991-92 to 2000-01 and 2001-02 to 2010-11

TIME PERIODS	STATES							
	A.P.	ASSAM	BIHAR	GUJ	HAR	KAR	KERA	M.P.
TP								
1991-92 to 1999-00 (Decade-1 of Post-reform period)	4.24	3.03	5.36	6.06	4.23	4.55	2.78	5.55
2000-01 to 2010-11 (Decade-2 of Post-reform period)	3.00	2.52	4.39	5.24	2.87	3.85	0.81	4.28
SC								
1991-92 to 1999-00 (Decade-1 of Post-reform period)	0.01	-0.43	0.20	-0.13	-0.19	-0.12	-0.07	0.09
2000-01 to 2010-11 (Decade-2 of Post-reform period)	-0.06	-0.23	-0.43	-0.27	-0.18	-0.24	0.04	-0.33
AEC								
1991-92 to 1999-00 (Decade-1 of Post-reform period)	-0.35	4.01	1.80	1.70	2.11	2.61	0.48	0.39
2000-01 to 2010-11 (Decade-2 of Postreform period)	4.70	-1.01	3.24	1.08	1.70	2.19	1.46	2.40
TFP								
1991-92 to 1999-00 (Decade-1 of Post-reform period)	3.90	6.61	7.36	7.64	6.15	7.04	3.19	6.04
2000-01 to 2010-11 (Decade-2 of Postreform period)	7.64	1.28	7.19	6.05	4.39	5.80	2.30	6.35
TIME PERIODS	STATES							
	MAHA	ODISHA	PUN	RAJ	T.N.	U.P.	W.B.	IND
TP								
1991-92 to 1999-00 (Decade-1 of Post-reform period)	5.47	6.11	4.05	5.15	4.24	5.61	4.23	5.74
2000-01 to 2010-11 (Decade-2 of Post-reform period)	4.35	5.36	1.84	3.28	2.83	3.53	3.03	4.47
SC								
1991-92 to 1999-00 (Decade-1 of Post-reform period)	-0.01	0.14	0.07	-0.05	-0.04	0.14	-0.11	0.02
2000-01 to 2010-11 (Decade-2 of Postreform period)	-0.08	-1.32	-0.05	-0.34	0.14	-0.10	-0.13	0.33
AEC								
1981-82 to 1990-91 (Pre-reform period)	0.98	0.55	-0.93	0.49	1.19	0.97	0.12	0.67
1991-92 to 2010-11 (Post-reform period)	1.64	3.92	2.36	1.52	2.03	0.55	3.24	1.59
TFP								
1991-92 to 1999-00 (Decade-1 of Postreform period)	6.44	6.81	3.18	5.59	5.38	6.73	4.24	6.43
2000-01 to 2010-11 (Decade-2 of Postreform period)	5.90	7.96	4.15	4.46	5.00	3.98	6.15	6.39

The organized manufacturing industries in India have not been benefitted from economies of scale.

Table 5 presents the rates of growth of total factor productivity (TFP), technological progress (TP), scale change (SC) and allocative efficiency change (AEC) during the two sub-periods in the post-reform period (1991-92 to 2000-01 and 2001-02 to 2010-11). We have noted above that the average annual growth rates of TFP during 1991-92 to 2010-11 declined from those in the pre-reform period of 1981-82 to 1990-91 in as many as 12 out of 15 states in India. When we sub-divide the entire post-reform period of 20 years into two sub-periods of 1991-92 to 1999-2000 and 2000-01 to 2010-11 we see that in as many as 10 states TFPG significantly declined from the first sub-period to the second sub-period. In all-India, too, there was a decline in the TFPG, though the amount of fall was negligible (only 4 percentage points). The states that registered higher growth rate of TFP in the second sub-period are A.P., M.P., Odisha, Punjab and West Bengal. Sharp declines in technological progress in all the states during the second sub-period are mainly responsible for this decline in TFPG from the first sub-period to the second sub-period.

Conclusion

The decomposition analysis shows that during the periods under study, technological progress has been the main driving force of productivity growth in the

organized manufacturing units in India as well as in the fifteen major industrialized states in India. The growth of technological progress of the organized manufacturing industries in all-India and in 15 major industrialized states in India has declined during the post-reform period. The technical efficiency of the organized manufacturing units is, however, found to be time-invariant in nature i.e., over-time changes in technical efficiency are not statistically significant. With respect to scale effect, its contribution to TFPG in Indian manufacturing has been very low or even negative. The change in allocative efficiency component shows that resource allocation in the organized manufacturing industries in India and in all the states in our study has improved during the post-reform period. This implies that deregulation and delicensing of the economy in the post-reform period has reduced the price distortion measured by the gap between price and marginal product in the organized manufacturing sector in all-India and in almost all the industrialized states in India.

Deregulation and delicensing of the economy in the post-reform period has reduced the price distortion.

Since the findings show that technological progress is the main source of TFPG in the organized manufacturing sector in all-India and in fifteen major Indian states further study is needed to understand what drives the productivity growth of the manufacturing industries at more disaggregated levels.

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