Output & Productivity Growth Decomposition: A Panel Study of Manufacturing Industries in India

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This paper decomposes output and productivity growth of thirteen 2-digit manufacturing industries as well as total manufacturing industry in India during 1981-82 to 2010-11. The four attributes of output growth are input growth, adjusted scale effect, technological progress and technical efficiency growth. A stochastic frontier model with a translog production function is used to estimate the growth attributes of the manufacturing industries. The results show that input growth is the major contributor to output growth whereas total factor productivity growth (TFPG) sometimes remains inadequate even though it has a positive and significant effect on output growth. Technological progress is found to be the major contributor to TFPG and the scale effect has become important during recent years.

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Introduction

In studying the technological change in the US economy, Solow (1957) differentiated the movements along the production function and the shifts of the production function. The former is caused by the input growth while the latter is defined as technological progress. Assuming constant returns to scale and perfect competition in the product market, he showed that the growth of output per unit of labor can be decomposed into technological progress and the weighted growth of capital per unit of labor. Alternatively, technological progress can be estimated with the time series data of output per unit of labor, capital per unit of labor, and the share of capital. This measure of technological progress is known as "Solow residual"[1].The residual is

[1]The standard measure of total factor productivity growth is the Solow residual: that part of output growth that cannot be accounted for by the growth of the primary factors of production, i.e. capital and labor.

calculated by subtracting the growth of the primary inputs (weighted by their respective shares in nominal output) from the growth of output. Under "Solow residual approach", technological progress is usually considered to be the unique source of total factor productivity (TFP) growth. Under this approach TFP growth can be defined as the residual of output growth after the contributions of labor and capital inputs are subtracted from total output growth. This approach is based on the assumption that the economies are producing along the production possibility frontier with full technical efficiency (it does not allow inefficiency). Thus under "Solow residual" approach TFP growth is shown by solely shifting the production possibility frontier.

While the neo-classical approach of TFP analysis often assumes optimality in production capacity, the output-oriented stochastic frontier production approach (Aigner et al., 1977) argues that, with given sets of factor inputs and due to possible technical inefficiency, there can be difference between actual and optimal output. The measure of technical inefficiency can thus be added to the analysis of TFP growth by using the stochastic frontier model. This study extends the production function approach of TFP measure and follows Denny et al. (1981), Bauer (1990), and Kumbhakar & Lovell (2000) to examine the theoretical foundations of the decomposition of output and productivity growth. We relax the assumption of constant returns to scale and consider technical inefficiency in a stochastic frontier model. The output growth is then decomposed into: input growth and TFP growth and once again TFP growth is decomposed into: adjusted scale effect (ASE), technological progress ($\dot{TP}$) and the technical efficiency growth ($\dot{TE}$) (Kumbhakar & Lovell, 2000).

In our study we decomposed output and TFP growth of the thirteen 2-digit manufacturing industries in India namely, manufacture of food products (20-21), manufacture of beverages and tobacco products (22), manufacture of textile and textile products (23+24+25+26), manufacture of wood and wood products; furniture and fixtures (27), manufacture of paper and paper products (28), manufacture of leather and leather products (29), manufacture of chemicals and chemical products (30), manufacture of rubber, petroleum and coal products (31), manufacture of non-metallic mineral products (32), manufacture of basic metals and alloys (33), manufacture of metal products (34), manufacture of machinery and transport equipments (35+36+37), other manufacturing industries (38) and total manufacturing industry assuming that the afore-mentioned industries 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 over a period from 1981-82 to 2010-11[during the entire period, pre-reform period (1981-82 to 1990-91), post-reform-period (1991-92 to 2010-11) and during two different decades of the post-reform period, i.e., during 1991-91 to 2000-01 and during 2001-02 to 2010-11], we have decomposed output growth of the organized manufacturing industries into input and TFP growth and again TFP growth into adjusted scale effect, technological progress and technical efficiency effect. This decomposition of output and TFP growth of the organized manufacturing industries 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. The following section discusses the theoretical foundations of the decomposition of output and productivity growth[2].

Decomposing Output & Productivity Growth

Neo-classical growth models assume that there exists always technical efficiency and production occurs on the production frontier. But the existence of technical inefficiency cannot be ruled out altogether. The stochastic frontier model (Aigner et al., 1977; Battese & Coelli, 1988; 1992; Greene, 2005) can be used to check whether there exists technical inefficiency in production. The model is given by:

$$Y_t = F(X_{1t}, X_{2t}, \ldots, X_{nt}, t)\, e^{-u_t} \quad \text{...........(1)}$$

where Y is the actual level of output; F is the potential production function with 'n' inputs; X_{it} is i^{th} input; and 'u' is a half-normally distributed random variable with a positive mean. The inclusion of 't' in 'F' allows for the production function to shift over time due to technological progress. The last term e^{-u_t} measures technical inefficiency.

[2]The empirical study of the decomposition of TFP growth has earlier been applied to Korea with the production function approach by Kim and Han (2001) and to the U.S. by Sharma et al. (2007).

Taking logarithm on both sides of (1) yields-

$$\log Y_t = \log F(X_{1t}, X_{2t}, \ldots, X_{nt}, t) - u_t \quad \text{......(2)}$$

Technical inefficiency occurs when $u_t > 0$ and the level of $\log Y_t$ is less than the level of log F. Differentiating Equation (2) with respect to time yields the following output growth equation:

$$\dot{Y}_t = \sum_i \frac{\partial F}{\partial X_{it}} \frac{X_{it}}{F} \dot{X}_{it} + \frac{\partial F / \partial t}{F} \quad \frac{\partial u_t}{\partial t} \quad ..(3)$$

where $\dot{Y}_t = \frac{\partial Y_t / \partial t}{Y_t}$ is the growth of output and $\dot{X}_{it} = \frac{\partial X_{it} / \partial t}{X_{it}}$ is the growth of input X_{it}.

Define $e_{it} = \frac{\partial F}{\partial X_{it}} \frac{X_{it}}{F}$ as the output elasticity for input X_{it}. Let $e_t = \sum_i e_{it}$ (the sum of the elasticity to each input). It can be shown that e_t is a measure of returns to scale. The production shows increasing (constant, decreasing) returns to scale when $e_t > 1$ (= 1, < 1).

Define the technical efficiency (TE) as the ratio of the actual output and the potential output, $TE_t = \frac{Y}{F} = e^{-u_t}$. Then, the growth of the technical efficiency,

$$\dot{TE}_t = -\frac{\partial u_t}{\partial t} \quad \text{..........................(4)}$$

The output growth can therefore be presented as

$$\dot{Y}_t = \sum_i e_{it} \dot{X}_{it} + \dot{A}_t + \dot{TE}_t \quad \text{.......................(5)}$$

Consider the following cost minimization problem under perfect competition in the factor markets, but not necessary in the product market.

$$\min_{X_{it}} C_t = \sum_i w_{it} X_{it} \quad \text{subject to } Y_t = F(X_{1t}, X_{2t}, \ldots, X_{nt}, t)\, e^{-u_t} \quad \text{....................(6)}$$

We express the objective function and the constraint in the following Lagrangian form,

$$L(X_{it}, \lambda) = \sum_i w_{it} X_{it} + \lambda\,(Y_t - F\, e^{-u_t}) \quad \text{...(7)}$$

where λ is the Lagrange multiplier. The first-order condition for minimization requires,

$$w_{it} = \lambda \frac{\partial F}{\partial X_{it}} e^{-} = \lambda \frac{\partial F}{\partial X_{it}} \frac{F}{X_{it}} e^{-u_t}$$

$$= \lambda e_{it} \quad \text{..(8)}$$

Multiplying both sides by X_{it},

$$w_{it} X_{it} = \lambda e_{it} Y_t \quad \text{...............................(9)}$$

Taking the sum of all inputs, the total cost is

$$\sum_i w_{it} X_{it} = \sum_i \lambda e_{it} Y_t \quad \text{.....................(10)}$$

or $Ct = \lambda e_t Y_t$ ....(11)

where C_t is the total cost of production at time 't'

Denote the cost share of input X_{it} as S_{it}. Dividing equation (9) by equation (11), the cost share is

$$S_{it} = \frac{w_{it} X_{it}}{C_t} = \frac{e_{it}}{e_t} \quad \text{..........................(12)}$$

This shows that the cost share is always equal to the relative output elasticity in the case of cost minimization[3]. We can rewrite the output growth Equation (5) as

$$\dot{Y}_t = e_t \sum_i \frac{e_{it}}{e_t} \dot{X}_{it} + \dot{A}_t + \dot{TE}_t \quad \text{.........(13)}$$

By adding and subtracting term,

$$\dot{Y}_t = \sum_i \frac{e_{it}}{e_t} \dot{X}_{it} +$$

$$+ \dot{A}_t + \dot{TE}_t \quad \text{.................................(14)}$$

Using Equation (12),

$$\dot{Y}_t = \sum_i s_{it} \dot{X}_{it} + \quad + \dot{A}_t$$

$$+ \dot{TE}_t \quad \text{...(15)}$$

Equation (14) shows the decomposition without cost information (w) and can be used for the empirical estimation of the sources of output growth, if the parameters of the production function are known. Equation (15) shows that output growth can be decomposed into four components: weighted sum of input growth, adjusted scale effect, technological progress, and growth of technical efficiency.

[3] Kumbhakar and Lovell (2000) include the allocative inefficiency component in their decomposition. In this model allocative inefficiency does not exist as the cost minimization is used.

For the first term in equation (14), the weight for each input growth is equal to the cost share of each input. The second term represents the adjusted scale effect. When the returns to scale are constant, this term is zero. For the production with increasing returns to scale, $e_t > 1$, a part of returns to scale (e_t-1) contributes to the output growth if aggregate input growth is positive. The contribution from returns to scale (e_t-1) is weighted by the aggregate input growth $\sum_i s_{it} \dot{X}_{it}$. If the aggregate input growth is zero, then the scale effect is zero.

The first two terms in equation (15) show that input growth has two impacts on output growth. One is the direct impact through its growth and the other is the indirect impact through scale effect. The decomposition in equations (14) and (15) has relaxed a major assumption in Solow's (1957) decomposition of economic growth, as equation (15) does not require the constant returns to scale assumption. Indeed, the growth decomposition as shown by equations (14) and (15) can be applied to any type of production function as long as output elasticity for each input can be derived. This implies that a nonlinear production function such as the translog production function can be used for growth decomposition analysis.

Total factor productivity (TFP) is defined as

$$TFP_t = \frac{Y_t}{\Phi_t} \quad \text{...(16)}$$

where Φ is the aggregate input. Taking logarithm and differentiating with respect to time, the TFP growth becomes

$$\dot{TFP}_t = \dot{Y}t - \quad \text{............................(17)}$$

Although it is not feasible to measure 'Φ' since it is the aggregate of different inputs with different unit of measurements, a commonly used measure of input growth is the Divisia Index (Jorgenson & Griliches, 1967),

$$\dot{\Phi}_t = \sum_i \frac{w_{it} X_{it}}{C_t} \dot{X}_{it} = \sum_i s_{it} \dot{X}_{it} \quad \text{......(18)}$$

Substituting equations (15) and (18) into (17), the TFP growth becomes

$$\dot{TFP}_t = (e_t - 1)\sum_i s_{it} \dot{X}_{it} + \dot{A}_t + \dot{TE}_t \quad \text{...(19)}$$

Thus TFP growth has three components: adjusted scale effect, technological progress, and growth of technical efficiency (Bauer, 1990; Kumbhakar & Lovell, 2000: 284)[4].

Functional Form

The empirical estimation involves the panel data estimation of the thirteen 2-digit manufacturing industries as well as total manufacturing industry in India for the sample period from 1981-82 to 2010-11. The output for the production function is the real value-added (Y) of the thirteen 2-digit manufacturing industries and total manufacturing in India and the inputs are labor (L)

[4] When there exists constant returns to scale in the production process, e_t=1, and if there is no technical inefficiency, the decomposition is reduced to $\dot{TFP}_t = \dot{A}_t$ as in Solow (1957).

indicated by the total number of employees and capital (K). The estimation model is the production function with a second-order transcendental logarithmic (translog) form,

$$LnY_{it}=\beta_0+\beta_L lnL_{it}+\beta_K lnK_{it}+\beta_t t+1/2\beta_{LL}L_{it}^2+1/2\beta_{KK}K_{it}^2+1/2\beta_{tt}t^2+\beta_{LK}lnL_{it}lnK_{it}+\beta_{Lt}L_{it}t+\beta_{Kt}K_{it}t+v_{it}-u_{it} \quad ....(20)$$

where the subscript 'i' is the i^{th} industry and 't' is the time period. The random error v_{it} is symmetric and normally distributed with $v_{it}\sim N(0, \sigma_v^2)$ and u_{it} is a non-negative truncated normal random error with the probability distribution of $N(\mu,\sigma_u^2)$, where μ is the mode of normal distribution.

The non-negative property of the random error u_{it} is used to measure technical inefficiency as in equation (4). Technical inefficiency can either be time variant (u_{it}) or time invariant (u_i).

where the technical inefficiency function is assumed to be defined by

$$u_{it}=\delta_0+\delta_1 SK_{it}+\delta_2 KI_{it}+\delta_3 DT_{it}+w_{it}....(21)$$

where Y_{it}, L_{it} and K_{it} are respectively the value added, labor input, and capital input for the aggregate manufacturing industry in industry 'i' at time 't'; SK_{it} denotes the index of employers' skill in the organized manufacturing industries of the i^{th} industry in the year 't' measured by the ratio of the number of employees other than workers to total number of employees; KI_{it} denotes the capital intensity of the organized manufacturing industries of the i^{th} industry in the year 't' measured by the ratio of the stock of fixed capital to total number of employees and DT_{it} is the slope dummy which shows the impact of economic reforms on productivity growth (D_{it} takes the value 'o' during the pre-reform period and it takes the value '1' during the post-reform period); w_{it} is the random error term, distributed as $N(0, \sigma^2)$ truncated at $-z_{it}\delta$, which ensures that $u_{it}\geq 0$.

The stochastic frontier production function defined by equation (20), and the technical inefficiency effects, specified by equation (21) can be jointly estimated by the maximum likelihood estimation (MLE) method using the software such as FRONTIER, LIMDEP etc. In this paper, we have employed FRONTIER 4.1 (Coelli, 1996) to estimate the stochastic frontier model.

From Equation (20), the output elasticity of labor and capital for industry 'i' and time t, which are denoted as e_{Lit} and e_{Kit}, respectively, can be derived as follows:

$$e_{Lit}=\partial lnF/\partial lnL_{it}=\beta_L+\beta_{LL}lnL_{it}+\beta_{LK}lnK_{it}+\beta_{Lt}t \quad ....(22)$$

$$e_{Kit}=\partial lnF/\partial lnK_{it}=\beta_K+\beta_{KL}lnL_{it}+\beta_{KK}lnK_{it}+\beta_{Kt}t \quad ....(23)$$

The returns to scale is measured as $e_{it} = e_{Lit} + e_{Kit}$. The cost shares of inputs are $s_{Lit}=$ and $s_{Kit}=\frac{e_{K_{it}}}{e_{it}}$ ....(24)

The maximum likelihood method is generally used to estimate the parameters in a stochastic frontier production function (Battese & Coelli, 1995; Kumbhakar & Lovell, 2000). After estimating the parameters in equation (20), equations (22) and (23) are used for the calculation of output elasticities and the adjusted scale effect. Given the estimates of the parameters in equations (20) and (21), the technical efficiency level of the industry '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

$$TE_{it}=\exp(-u_{it}) \qquad (25)$$

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

$$TP_{it}=\partial \ln F/\partial t=\beta t+\beta_{tt}t+\beta_{Lt} \ln L_{it}+\beta_{kt} \ln K_{it} \qquad (26)$$

where βt 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) suggest that the geometric mean between the adjacent periods be used to estimate the TP component.

Data & Variables

This study is based on panel data collected from the various issues of Annual Survey of Industries (ASI) of the Central Statistical Organization (CSO) for the period from 1981-82 to 2010-11. The EPW database has also been utilized to obtain relevant data for the period 1981-82 to 2010-11. The variables used in this exercise are output and labor and capital inputs. Deflated value added has been taken as the measure of output. The ratio of nominal and real GDP, the values of which are obtained from different volumes of NAS is treated here as deflator. Total number of persons engaged is used as the measure of labor input. Since working proprietors / owners and supervisory and managerial staff have a significant influence on the productivity of a firm, the number of persons engaged was preferred to the total number of workers as a proxy for labor. Total emoluments divided by total number of persons engaged in production is considered as price of labor input in our study. Net fixed capital stock at constant prices has been taken as the measure of capital input. The net fixed capital stock series has been constructed from the series on gross fixed capital (at constant prices) using the Perpetual Inventory Method. The annual rate of depreciation of fixed assets has been taken as 5 per cent. Rental price of capital equals the ratio of interest paid and capital invested (Jorgenson & Griliches, 1967) is assumed to be price of capital in our study.

Proper Model Specification

In this study the FRONTIER 4.1 software program developed by Coelli (1992 & 1995) is used. It enables us to undertake a one-step estimation of the stochastic frontier model as well as the parameters of the variables to explain efficiency. Various tests of hypotheses of the parameters in the frontier function is performed using the generalized likelihood ratio-test statistic, defined by

$$\lambda = -2\,[L\,(H_0)\text{-}L\,(H_1)]$$

where L (H_0) is the log-likelihood value of a restricted frontier model, as specified by a null hypothesis, H_0; and L (H_1) is the log-likelihood value of the general frontier model under the alternative hypothesis, H_1. This test statistic has approximately a chi-square distribution (or a mixed chi-square) with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses. If the inefficiency effects are absent from the equation, as specified by the null hypothesis H_0: γ=0, then the statistic λ is approximately distributed according to a mixed chi-square distribution. Table 1 presents the test results of various null hypotheses.

The first likelihood test is conducted to test the null hypothesis that the translog stochastic frontier production function can be reduced to a Cobb-Douglas. The test statistic H_0: $\beta_{LL}=\beta_{KK}=\beta_{LK}=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$ as shown in Table 1 has a likelihood ratio value 38.84, which implies rejection of the null hypothesis at 1% significance level. In other words, the translog model could not be reduced to a Cobb-Douglas model and is, hence, the ideal model.

The second test we have conducted in this study is testing the null hypothesis that there is no technological change over time i.e. H_0: $\beta_t=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$. The value of the test statistic as shown in Table 1 is 62.16 which is significantly larger than the critical value of 13.28 at 1% probability level. As a result, the null hypothesis of 'no technological change over time' is rejected.

The third null-hypothesis is that the technological progress is neutral i.e., H_0: $\beta_{Lt}=\beta_{Kt}=0$. The value of the test statistic in this case becomes 26.6 which is greater than the critical value of 9.21 at 1% probability level. This indicates that the translog parameterization of the stochastic frontier model does not allow for neutral technological progress.

Fourth, testing the model specification shows that the null-hypothesis that technical inefficiency effects are absent, i.e., $H_0=\gamma=\delta_0=\delta_1=\delta_2=\delta_3=0$, is rejected (Table 1). This implies that the traditional production function is not an adequate representation for the 2-digit manufacturing industries in India. In this case, it can be said that inefficiencies are present in the 2-digit manufacturing industries in India and they are stochastic.

The fifth null hypothesis asserts that the variables included in the inefficiency effects model have no effect on the level of technical inefficiency, i.e., $H_0= \delta_1= \delta_2= \delta_3=0$.The test result shows that the null hypothesis is rejected confirming that the joint effect of these explanatory variables on technical inefficiency is statistically significant (Table 1).

The final null-hypothesis specifies that each production unit is operating on the technically efficient frontier and that the asymmetric and random technical efficiency in the inefficiency effects are

Table 1 Hypothesis Tests for Model Specification

Null Hypothesis	Log- like lihood Value	Test stati stics λ= -2[L(H_0)- L(H_1)]	Critical value at 1% level	Critical value at 5% level	Decision
Cobb-Douglas Production Specification $H_0=\beta_{LL}=\beta_{KK}=\beta_{LK}=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$	-157.70	34.84	16.81	12.59	Reject H_0
No technological change$H_0=\beta_t=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$	-171.36	62.16	13.28	9.49	Reject H_0
Neutral technological change$H_0=\beta_{Lt}=\beta_{Kt}=0$	-152.58	26.60	9.21	5.99	Reject H_0
No technical inefficiency effects $H_0=\gamma=\delta_0=\delta_1=\delta_2=\delta_3=0$	-172.74	64.92	16.81	14.45	Reject H_0
Exogenous variables included in the inefficiency effects model have no effect on the level of technical inefficiency $H_0=\delta_1=\delta_2=\delta_3=0$	-172.74	64.92	15.08	11.07	Reject H_0
Each industry is operating on the technical efficient frontier and the asymmetric and random technical efficiency is zero$H_0=\mu=0$	-142.51	4.46	6.63	3.84	Reject H_0 at 5% level

zero (H_0:μ=0). This hypothesis is also rejected in favor of the presence of inefficiency effects at 5% level of significance.

Empirical Results

The estimation of parameters in the stochastic frontier model given by equations (20) and (21) are carried out by maximum-likelihood (ML) method, using the program FRONTIER 4.1(Coelli, 1996). Instead of directly estimating σ^2_v and σ^2_u FRONTIER 4.1 seeks to estimate $\gamma=\sigma^2_u/\sigma^2$ and $\sigma^2=\sigma^2_v+\sigma^2_u$, 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 γ=0 is accepted, this would indicate that σ^2_u 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.

Table 2 reports the maximum likelihood estimates of the stochastic frontier production function fitted to the total 434 observations for a panel of thirteen 2-digit manufacturing industries as well as total manufacturing in India during the period of 1981-82 to 2010-11. The maximum likelihood estimates for the translog stochastic frontier production function are reported in panel 1 of Table 2. As under translog specification there may exist high level of multicollinearity due to the interaction and squared terms, certain estimated coefficients are found to be statistically insignificant. Panel 2 of Table 2 reports the estimated coefficients for the technical inefficiency effects model. All the coefficients of the technical inefficiency effects model except that of capital intensity (K/L) are found to be statically significant which implies that a considerable amount of output variation is due to the presence of technically inefficiency effect.

The estimated value of δ_1 is found to be negative and statistically significant at 1% probability level which implies that an increase in employees' skill will lower the technical inefficiency effects. The estimated value of δ_2 is also found to be negative though it is not statistically significant. The estimated value of δ_3 is, however, found to be positive and statistically significant too at 10% probability level, indicating that economic reforms have boosted technical inefficiency effects of the 2-digit manufacturing industries in India.

Economic reforms have boosted technical inefficiency effects of the 2-digit manufacturing industries in India.

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

Variables	Parameters	Coefficients	Standard Errors	t-statistics
Panel-1: Stochastic frontier production model				
Constant	β_0	2.23	2.56	0.87
lnL	β_L	-1.04*	0.79	-1.32
lnK	β_K	1.83***	0.48	3.79
T	β_t	-0.126***	0.03	-3.84
lnL^2	β_{LL}	0.131**	0.06	2.28
lnK^2	β_{KK}	0.025	0.029	0.86
t^2	β_{tt}	-0.0002	0.0003	-0.70
lnL*lnK	β_{LK}	-0.158**	0.0728	-2.17
lnL*t	β_{Lt}	0.015***	0.0053	2.76
lnK*t	β_{Kt}	0.002	0.0045	-0.37
Panel-2: Technical inefficiency effects model				
Constant	δ_0	1.12 **	0.21	5.21
Employees Skill(OE/TE)	δ_1	-3.09***	0.42	-7.39
Capital Intensity(K/L)	δ_2	-0.08	0.09	-0.93
Slope Dummy(DT)	δ_3	0.014*	0.01	1.46
Panel-3: Variance parameters				
Sigma squared	σ^2	0.12***	0.01	10.31
Gamma	γ	0.42**	0.20	2.11
Log-Likelihood		-140.28		

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

Panel 3 of Table 2 reports the estimates of the variance parameters σ^2 and γ that test for the validity of technical inefficiency effect. Both the estimated coefficients are found to be statistically significant at 1% probability level which confirms the presence of technical inefficiency effect in the output residual as indicated in panel 3. However, the estimated value of γ is found to be 0.42, which is far below unity. This implies that output variation in the organized manufacturing industries in India is significantly dominated by random factors.

Input growth rate is found to be the major contributor to the output growth of the 2-digit manufacturing industries.

Based on the translog production function estimates shown in Table 2 we derived the following measures: the output elasticity with respect to factor inputs (e_L & e_K), returns to scale ($e=e_L+e_K$), the adjusted scale effect (*ASE*), rate of technological progress ($\dot{A}_t$), and the rate of growth of technical efficiency ($\dot{TE}_t$). These measures are then used to derive the components of the growth rates output and total factor productivity ($\dot{TFP}_t$). Because the translog specification is used, the performance of these measures varies depending on industries and years. For the four sources of the output growth, Tables (3) to (5) show that input growth rate is found to be the major contributor to the output growth of the 2-digit manufacturing industries in India. On an average, the primary inputs contribution accounts for about more than fifty percent of the output growth in the case of almost all the 2-digit manufacturing industries in India during the entire study period (1981-82 to 2010-11) as well as during both the pre-& post-reform periods (1981-82 to 1990-91 & 1991-92 to 2010-11). The technical efficiency effects in all the 2-digit industries are found to be negative during the entire period of our study as well as during the post-reform period although they are found to be positive in a few industries during the pre-reform period. However, the rates of technological progress ($\dot{A}_t$) in all the industries are found to be positive and they are found to be the major contributor to the total factor productivity growth ($\dot{TFP}_t$). The adjusted scale effects in almost all the industries are found to be negligible and in many industries they are even found to be negative. Although the scale effect is negative in a few cases it has increased significantly during the post-reform period. However, its estimates are still far below the estimates of technological progress both in the pre-and the post-reform periods. From these findings it may be concluded that although factor accumulation may have led to the TFP growth through increasing returns to scale, the most important factor of the TFP growth of organized manufacturing in India is technological progress. The estimates of the growth rate of output as well as the effects of primary inputs to output growth become maximum in the case of chemicals & chemical products (30) during the whole period as well as during the pre-reform period while the estimates of TP as well as TFPG rates reached their highest levels in the case of total manufacturing during the whole period, pre-reform period and the post-reform period.

The most important factor of the TFP growth of organized manufacturing in India is technological progress.

It is found that the contributions of primary inputs to output growth have increased during the post-reform period in almost all the 2-digit industries. However, the contributions of the TFPG have declined during the post-reform period. This

Table 3 Growth Rate of Output & Its Components (1981/82 – 2010/11)

Average Annual Growth Rate(%) of Output and its Components for the Thirteen 2-Digit Manufacturing Industries as well as Total Manufacturing in India during 1981-82 to 2010-11

Industries	$\dot{Y}$ (1=2+7)	$\dot{\Phi}$ (2)	$\dot{ASE}$ (3)	$\dot{A}$ (4)	$\dot{TE}$ (5)	$\dot{TFP}$ (7=3+4+5)
Food & Food Products (20-21)	6.80	2.32	0.21	4.92	-0.65	4.48
Beverages &Tobacco Products (22)	6.72	3.61	0.51	3.88	-1.28	3.11
Textiles & Textile Products (23+24+25+26)	6.63	2.52	0.20	5.27	-1.36	4.11
Wood & Wood Products(27)	6.31	5.63	0.61	1.38	-1.31	0.68
Paper & Paper Products(28)	6.30	4.16	-0.11	2.95	-0.70	2.14
Leather & Leather Products(29)	9.72	7.24	0.93	1.99	-0.44	2.48
Chemicals & Chemical Products(30)	11.64	9.30	-1.21	3.56	-0.01	2.34
Rubber, Petroleum & Coal Products (31)	6.36	4.13	-0.38	3.13	-0.52	2.23
Non-Metallic Mineral Products(32)	9.09	6.43	-0.18	3.56	-0.72	2.66
Basic Metals & Alloys(33)	7.38	4.89	-0.52	3.81	-0.80	2.49
Metal Products & Machinery (34+35+36)	8.31	4.36	0.19	4.75	-0.99	3.95
Transport Equipments (37)	9.21	6.58	-0.10	3.69	-0.96	2.63
Other Manufacturing Industries(38)	7.69	6.12	0.16	1.95	-0.56	1.57
Total Manufacturing	7.71	1.91	0.03	7.28	-1.51	5.80

decline in TFPG is mainly responsible for the decline in TP of the same during that period as it is found that TP is the major contributor to the TFPG of the Indian manufacturing industries during the period of our study. From Table 4 (Panel 1 and Panel 2) it is found that the share of technological progress ($\dot{A}$) has been greater than that of the primary inputs of labor and capital, $\dot{\Phi}$, in the pre-reform period in as many as eight industries while in the post-reform period (1991-92 to 2010-11) the same has happened in the case of just three industries. The industries for which the contribution of $\dot{A}$ is greater than that of $\dot{\Phi}$ during both the pre-and post-reform periods are 20-21, 22 and 23+24+25+26. Interestingly, during the post-reform period the contribution of primary inputs effect has been significantly higher than that during the pre-reform period for most of the industries, and the contribution of,i.e., the technological progress to the output growth ($\dot{Y}$) in the post-reform period has been significantly lower than that in the pre-reform period. In general, while during the pre-reform period the technological progress has made maximum contribution to the output growth in all the industries, the contribution of primary inputs is found to be maximum for nine industries in the post-reform period. As far as the effect of technical efficiency is concerned, it has been positive for ten industries in the pre-reform period although it has no significant contribution to output growth. However, the effect of TP has been positive for all the industries during the entire study period (1981-82 to 2010-11), pre-reform period (1981-82 to 1990-91), post-reform period (1991-92 to 2010-11) and during the decades of the post-reform period (i.e., during 1991-92 to 2000-01 and 2001-02 to 2010-11).

Table 4 Growth Rate of Output & Its Components during Pre &Post- Reform Periods

Panel 1 Average Annual Growth Rate(%) of Output and its Components of the Thirteen 2-Digit Manufacturing Industries as well as Total Manufacturing in India during 1981-82 to 1990-91 (Pre-reform Period)

Industries	$\dot{Y}$ (1=2+7)	$\dot{\Phi}$ (2)	$A\dot{S}E$ (3)	$\dot{A}$ (4)	$T\dot{E}$ (5)	$T\dot{F}P$ (7=3+4+5)
Food & Food Products (20-21)	7.56	0.41	0.06	5.29	1.80	7.15
Beverages &Tobacco Products (22)	9.07	4.20	0.50	4.27	0.10	4.87
Textiles & Textile Products (23+24+25+26)	5.79	0.45	0.02	5.72	-0.39	5.35
Wood & Wood Products(27)	4.21	1.07	-0.08	1.85	1.37	3.14
Paper & Paper Products(28)	6.76	2.84	-0.33	3.40	0.85	3.92
Leather & Leather Products(29)	10.33	7.27	0.37	1.92	0.77	3.06
Chemicals & Chemical Products(30)	19.33	17.90	-2.84	3.14	1.13	1.43
Rubber, Petroleum & Coal Products (31)	-0.60	-5.31	0.68	3.83	0.20	4.71
Non-Metallic Mineral Products(32)	11.01	6.54	-0.57	3.92	1.12	4.47
Basic Metals & Alloys(33)	7.22	3.97	-0.71	4.27	-0.31	3.25
Metal Products & Machinery (34+35+36)	9.33	3.35	-0.16	5.10	1.04	5.98
Transport Equipments (37)	9.22	6.36	-0.63	4.15	-0.66	2.86
Other Manufacturing Industries(38)	7.90	6.02	-0.10	1.82	0.16	1.88
Total Manufacturing	7.86	0.66	-0.05	7.69	-0.44	7.20

Panel 2 Average Annual Growth Rate(%) of Output and its Components of the Thirteen 2-Digit Manufacturing Industries as well as Total Indian Manufacturing in India during 1991-92 to 2010-11 (Post-reform Period)

Industries	$\dot{Y}$ (1=2+7)	$\dot{\Phi}$ (2)	$A\dot{S}E$ (3)	$\dot{A}$ (4)	$T\dot{E}$ (5)	$T\dot{F}P$ (7=3+4+5)
Food & Food Products (20-21)	6.41	3.27	0.29	4.72	-1.87	3.14
Beverages &Tobacco Products (22)	5.54	3.31	0.52	3.68	-1.97	2.23
Textiles & Textile Products (23+24+25+26)	7.05	3.56	0.29	5.05	-1.85	3.49
Wood & Wood Products(27)	7.37	7.91	0.96	1.15	-2.65	-0.54
Paper & Paper Products(28)	6.08	4.82	0.01	2.73	-1.48	1.24
Leather & Leather Products(29)	9.42	7.23	1.21	2.03	-1.05	2.19
Chemicals & Chemical Products(30)	7.78	4.98	-0.40	3.78	-0.58	2.80
Rubber, Petroleum & Coal Products (31)	9.83	8.86	-0.92	2.78	-0.89	0.97
Non-Metallic Mineral Products(32)	8.13	6.38	0.02	3.36	-1.63	1.75
Basic Metals & Alloys(33)	7.46	5.35	-0.43	3.58	-1.04	2.11
Metal Products & Machinery (34+35+36)	7.80	4.86	0.36	4.58	-2.00	2.94
Transport Equipments (37)	9.21	6.69	0.17	3.46	-1.11	2.52
Other Manufacturing Industries(38)	7.59	6.18	0.29	2.04	-0.92	1.41
Total Manufacturing	7.62	2.53	0.06	7.07	-2.04	5.09

Table 5 Growth Rate of Output & Its Components during 1991/92-2000/01& 2001/02- 2010/11

Panel 1 Average Annual Growth Rate(%) of Output and its Components of the Thirteen 2-Digit Manufacturing Industries as well as Total Manufacturing in India during 1991-92 to 2000-01 (Decade 1: Post-reform Period)

Industries	$\dot{Y}$ (1=2+7)	$\dot{\Phi}$ (2)	$A\dot{S}E$ (3)	$\dot{A}$ (4)	$T\dot{E}$ (5)	$T\dot{F}P$ (7=3+4+5)
Food & Food Products (20-21)	6.87	3.43	0.18	4.93	-1.67	3.44
Beverages &Tobacco Products (22)	7.18	4.96	0.74	3.97	-2.49	2.22
Textiles & Textile Products (23+24+25+26)	5.85	3.20	0.08	5.19	-2.62	2.65
Wood & Wood Products(27)	4.20	7.07	0.55	1.26	-4.68	-2.83
Paper & Paper Products(28)	5.32	4.72	-0.26	2.94	-2.08	0.60
Leather & Leather Products(29)	5.56	6.06	0.54	1.96	-3.00	-0.50
Chemicals & Chemical Products(30)	8.81	6.65	-0.82	3.91	-0.93	2.16
Rubber, Petroleum & Coal Products (31)	7.78	8.33	-1.12	2.86	-2.29	-0.55
Non-Metallic Mineral Products(32)	6.51	4.61	-0.33	3.38	-1.15	1.90
Basic Metals & Alloys(33)	3.83	2.31	-0.45	3.69	-1.72	1.52
Metal Products & Machinery (34+35+36)	4.25	2.20	-0.01	4.72	-2.66	2.05
Transport Equipments (37)	6.29	4.85	-0.10	3.61	-2.10	1.44
Other Manufacturing Industries(38)	9.78	7.66	0.13	1.99	-0.01	2.12
Total Manufacturing	4.48	0.10	-0.07	7.26	-2.81	4.38

Panel 2 Average Annual Growth Rate(%) of Output and its Components of the Thirteen 2-Digit Manufacturing Industries as well as Total Manufacturing in India during 2001-02 to 2010-11 (Decade 2: Post-reform Period)

Industries	$\dot{Y}$ (1=2+7)	$\dot{\Phi}$ (2)	$A\dot{S}E$ (3)	$\dot{A}$ (4)	$T\dot{E}$ (5)	$T\dot{F}P$ (7=3+4+5)
Food & Food Products (20-21)	5.95	3.11	0.40	4.52	-2.08	2.84
Beverages &Tobacco Products (22)	3.90	1.65	0.3=0	3.39	-1.44	2.25
Textiles & Textile Products (23+24+25+26)	8.24	3.92	0.50	4.90	-1.08	4.32
Wood & Wood Products(27)	10.53	8.75	1.37	1.03	-0.62	1.78
Paper & Paper Products(28)	6.84	4.93	0.27	2.52	-0.88	1.91
Leather & Leather Products(29)	13.27	8.40	1.88	2.09	0.90	4.87
Chemicals & Chemical Products(30)	6.76	3.32	0.03	3.63	-0.22	3.44
Rubber, Petroleum & Coal Products (31)	11.89	9.38	-0.72	2.71	0.52	2.51
Non-Metallic Mineral Products(32)	9.75	8.14	0.37	3.35	-2.11	1.61
Basic Metals & Alloys(33)	11.08	8.39	-0.40	3.45	-0.36	2.69
Metal Products & Machinery (34+35+36)	11.34	7.51	0.73	4.44	-1.34	3.83
Transport Equipments (37)	12.15	8.54	0.42	3.30	-0.11	3.61
Other Manufacturing Industries(38)	5.40	4.69	0.46	2.08	-1.83	0.71
Total Manufacturing	10.78	4.97	0.20	6.88	-1.27	5.81

TP achieved during the first half had the lagged effect on TFPG during the latter half of the post-reform period.

From Table 5 (Panel 1 and Panel 2) it is found that the rate of growth of TP of the 2-digit industries has been greater during the first half of the post-reform (1991-92 to 2000-01) period than in the second half (2001-02 to 2010-11). However, the rate of growth of TFPG has been greater in the second half of the post-reform period compared to the first half. This may be due to the fact that the positive effect of TP during the first half of the post-reform period (1991-92 to 2000-01) could be realized during the latter half of the post-reform period (2001-02 to 2010-11). That is, the TP achieved during the first half had the lagged effect on TFPG during the latter half of the post-reform period.

Conclusions

This paper examines and applies the theoretical foundations of the decomposition of output and productivity growth of the thirteen 2-digit manufacturing industries as well as total manufacturing industry in India during pre-and post-reform periods and also during two different decades of the post-reform period. Our theoretical discussion follows that of Solow (1957), Denny et al. (1981), Bauer (1990), and Kumbhakar & Lovell (2000) and it shows that cost information is not required in estimating the components of output growth and the production function approach is sufficient for that empirical work. Output growth is decomposed into input growth, adjusted scale effect, technological progress, and growth in technical efficiency. With this decomposition, the TFP growth simply contains the last three components. The growth of aggregate input is the weighted sum of each input growth and the weight is the cost share of each input. The adjusted scale effect depends on the size of returns to scale. This effect is zero for constant returns to scale, but is adjusted by the aggregate input growth for increasing and decreasing returns to scale. Technological progress in the decomposition represents the shift of the production function over time. The technical efficiency is measured and derived from stochastic frontier model. For our empirical work on the production function, we have derived the series of capital stocks data using the inventory accumulation method for the thirteen manufacturing industries in India and for the total Indian manufacturing during the period from 1981-82 to 2010-11.

We have followed the decomposition of output and TFP growth analysis in Li and Liu (2011) using stochastic frontier analysis. We estimated the stochastic frontier translog production function using the maximum-likelihood estimation method. Our empirical results show that the two primary factor inputs (labor and capital) have played a significant role in the growth of output of the manufacturing industries in India. When the three sources of the growth of TFP are considered, we found that the major contributor to the TFPG is technological progress. The contribution from the adjusted scale effect (ASE) is also increasing in the recent years (shown in Table 3 of Panel 1 and Panel 2). However, this change is not encouraging at all. Technical inefficiency has been persisting throughout the post-reform period as evidenced by the negative values of $\dot{TE}$ in both the first and second decades of the post-reform period i.e., during 1991-92 to 2000-01 and 2001-02 to 2010-11 respectively.

Technical inefficiency has been persisting throughout the post-reform period.

The empirical results bring forward several policy implications on the sustainability of the post-reform Indian economy. Policies should be geared to utilize resources optimally and thereby to improve technical efficiency of the manufacturing industries in India. Although labor is plentiful, developed human capital is scarce in India. So it is necessary to develop more human capital in the country that may change the time path of scale from negligible to higher values and reverse the time path of technical inefficiency from negative to significantly positive values.

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Appendix: Concordance among NIC'87, NIC'98, NIC'04 and NIC'08

NIC'87 code	NIC'98 & NIC'04 code	NIC 2008 code
20-21	151-154	101-108
22	155+160	110+120
23+24+25+26	171+172+173+181	131+139+141+143
27	20+361	16+310
28	21+22	17+18
29	!82+191+192	142+151+152
30	24	20+21
31	23+25	19+22
32	26	23
33	271+272+273+371	241+242+243
34+35+35	28+29+30+31+32	25+26+27+28
37	34+35	29+30
38	331+332+333+369	321+322+323+324+325+329