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Components of Productivity Growth of the Manufacturing Industries of Petroleum and Coal Products in India: An Interstate Analysis

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Abstract - **The study applies stochastic frontier approach to estimate and decompose the sources of total factor productivity growth (TFPG) of the 2-digit manufacturing industries of petroleum and coal products in fifteen major industrialized states in India as well as in All-India during the period from 1981-82 to 2010-11, during the entire period, during the pre-reform period (1981-82 to 1990-91) and post-reform period (1991-92 to 2010-11), and also during two different decades of the post-reform period, i.e., during 1991-92 to 2000-01 and 2001-02 to 2010-11. The components of TFPG are: technological progress (TP), technical efficiency change (TEC), economic scale change (SC) and allocation efficiency change (AEC). According to the estimated results, technological progress (TP) is the major contributing factor to TFPG of the organized manufacturing industries of petroleum and coal products in India and in its fifteen major industrializes states during 1981-82 to 2010-11. Further, TFPG of the 2-digit manufacturing industries of petroleum and coal products in India and in its fifteen major industrialized states declined during the post-reform period and the decline in TFPG of these 2-digit industries during that period is mainly accounted for by the decline in TP of the same during that period. However, allocation efficiency change (AEC) and economic scale change (SC) of them remain very negligible or even negative too in many states under study. Further, TEC of them remain unchanged or it is time invariant in nature as statistical tests suggest. So that increase in the combined effect of AEC and SC of them could not offset the decrease in their TP during that period. As a result TFPG of the 2-digit manufacturing industries of petroleum and coal products declined in India and its fifteen major industrialized states during the post-reform period.**

Keywords: **2-Digit Manufacturing Industries of Petroleum and Coal Products, Stochastic Frontier Production Function, Total Factor Productivity Growth, Technological Progress, Technical Efficiency Change, Scale Effect and Allocation Efficiency Effect**

I. INTRODUCTION

The Petroleum and Coal Products Manufacturing sector is based on the transformation of crude petroleum and coal into usable products. The dominant process is petroleum refining that involves the separation of crude petroleum into component products through such techniques as cracking and distillation. In addition, this sector includes establishments that primarily further process refined petroleum and coal products and produce products, such as asphalt coatings and petroleum lubricating oils. However, productivity growth of this sector remains very poor during the last few years. Be it mentioned that growth of the organized manufacturing sector is usually attributed to growth in factor inputs and improvements in total factor productivity (TFP).

While measuring the sources of output growth of the manufacturing industries, the contribution of total factor productivity growth (TFPG) is always estimated as a residual, after accounting for the growth of primary inputs such as labour and capital. If the industries operate on their production possibility frontier producing the maximum possible output or realizing the full potential of the technology, then it implies that improvement in TFP arises from technological progress. There are generally two measures of TFPG: the growth accounting measure and the production function estimation approach.

The objective of the growth accounting measure of TFPG is to determine how much output growth is due to the use of primary inputs and how much can be attributed to technological progress. In other words, growth accounting measure of TFPG determines how much of the growth can be explained by movements along a production function and how much should be attributed to shift in production function. However, this approach is based on the assumption that industries are operating along the production possibility frontier with full technical efficiency (it does not allow inefficiency). Further, under growth accounting approach it is assumed that there exists CRS (constant returns to scale) in the production process. The assumptions of perfect competition also holds true in this approach.

Whenever it is difficult to satisfy these assumptions, a direct econometric estimation of production function is usually undertaken, which however, has its own limitations. One of the major disadvantages of the production function approach (PFA) is the problem of identification of production function. Further, the problems of autocorrelation and multi-colinearity encountered in the use of PFA will provide misleading estimates obtained by this approach. A further drawback of this approach is the difficulty of explaining the econometric methodology to a wide range of users, as well as the difficulty in replicating and producing productivity estimates on an ongoing basis. Once again, if a more flexible form of production function (like translog production function) is used it would be difficult to equate output elasticities with factor shares. Further, in the production function approach, we relax the assumption of Hicks neutral technological progress.

However, both in the growth accounting approach as well as in the production function approach technological progress is usually considered to be the unique source of TFP growth. Given the limitations of these approaches and that TFPG has several sources other than the technological progress such as change in technical efficiency, economies of scale and allocative efficiency the research question boils down to decomposition of the sources of TFPG into several components other than technological progress. To find answer to this research question we propose to use the stochastic frontier model justification for which are given below. A stochastic frontier model is undertaken to decompose productivity growth as the model could minimize the intensity of the problems like multi-collinearity and autocorrelation and it has the ability to provide information on the specified production technology and technical inefficiency component.

Further, stochastic frontier analysis (SFA) assumes a given functional form for the relationship between inputs and output. When the functional form is specified, the unknown parameters of the function could be estimated using econometric techniques. Data envelop analysis (DEA) which is computationally more simple and has the advantage that it can be implemented without knowing the algebraic form of the relationship between outputs and inputs (i.e., we can estimate the frontier without knowing whether output is a linear, quadratic, exponential or some other function of inputs) can be used here too. However, as the parameters of the frontier production function cannot be estimated and their statistical significance cannot be judged using DEA approach, SFA remains better approach. Further, deviation from the frontier technology into their systematic and random components cannot be separated using DEA approach. These requirements make SFA computationally more demanding than DEA. Further, it has advantages over DEA when data noise is a problem.

II. LITERATURE REVIEW

The concept of TFP came into force after the works of Tinbergen (1942), Schmookler (1952), Kendrick (1956), Fabricant (1954), Abramovitz (1956) and Solow (1957). It was Abramovitz (1956) who first observed the growth of output occurring due to factors other than an increase in inputs. Solow (1957) showed that between 80 to 90 percent of the observed increase in output per head could not be explained by increase in capital per head and was attributed to productivity growth. Terleckyj (1974), Scherer (1982, 1987) and Griliches (1984) showed that technological advancement was the major source of productivity improvement for the American industry. There is an extensive empirical literature on total factor productivity growth of the Indian manufacturing sectors. Studies by Brahmananda, 1982; Goldar, 1986; Ahluwalia, 1991; Balakrishnan and Pushpangadan, 1994; Dholakia and Dholakia, 1994; Rao, 1996a; Shrivastava, 1996; Balakrishnan, Pushpangadan and Suresh Babu, 2000; Goldar, 2002; Pal, 2002; Goldar and Kumari, 2003 and Goldar, 2004 are most notable among them. However, in most of the above mentioned studies technological progress is considered to be the unique source of TFPG. Further, most of the studies have discussed the measurement of TFPG at an aggregate level of Indian manufacturing sector.

The stochastic frontier model has been intensively used to estimate and decompose TFP growth at the firm, industry, state, and even more at the national levels. Although a vast number of empirical applications have contributed to identify the sources of TFP growth by focusing on its decompositions, representative studies are Nishimizu and Page (1982), Baur (1990), Kumbhakar and Lovell (2000), Kim and Han (2001) and Sharma, Sylwester and Margono (2007) to mention only a few. Nishimizu and Page (1982) was the first to propose the de-composition of TFPG into efficiency changes and technological progress. Bauer (1990) estimated a translog cost frontier using data on the US airline industry to decompose TFPG into efficiency changes, technological progress, and scale changes.

By applying a flexible translog stochastic production frontier, Kumbhakar and Lovell (2000), Kim and Han (2001) and Sharma et al. (2007) decompose TFP growth into four components: technological progress (TP), changes in technical efficiency (TEC), changes in allocative efficiency (AEC) and economic scale effects (SC). In this study, we focus on the estimation and decomposition of TFPG of the 2-digit manufacturing industries of petroleum and coal products in India and in its fifteen major industrialized states into four components: technological progress (TP), changes in technical efficiency (TEC), changes in allocation efficiency (AEC) and economic scale effects (SC) during the period from 1981-82 to 2010-11, during the entire period, during the pre-reform period (1981-82 to 1990-91) and post-reform period (1991-92 to 2010-11), and also during two decades of the post-reform period, i.e., during 1991-92 to 2000-01 and 2001-02 to 2010-11 using stochastic frontier approach.

III. METHODOLOGY RELATING TO PRODUCTIVITY GROWTH DECOMPOSITION

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… N) at time ‘t’ (t=1… T); f (.) 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 term independently and identically distributed with mean zero, and variance σ^2_v, used to capture random variation 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 normal distribution with mean μ and variance σ^2_u.

From equation (1) rate of output growth can be expressed as

$$\dot{y}_{it}=TP_{it}+\sum_j \varepsilon_j \dot{x}_{jt} - du_{it}/dt \text{---------} (2)$$

The overall output growth is, therefore, not only affected by TP and changes in input use, but also by changes in technical inefficiency.

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

$$T\dot{F}P_{it}=\dot{y}_{it} - \sum_j S_j\dot{x}_{jt} \text{---------} (3)$$

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

By substituting equation (2) into equation (3), we get

$$T\dot{F}P_{it}=TP_{it} - du_{it}/dt+\sum_j (\varepsilon_j - S_j)\ \dot{x}_{jt}=TP_{it} - du_{it}/dt+(\epsilon-1)\sum_j \lambda_j\ \dot{x}_{jt}+\sum_j (\lambda_j - S_j)\ \dot{x}_{jt} \text{--------} (4)$$

Where $\epsilon=\sum_j \varepsilon_j$ denotes the measurement of returns to scale (RTS) and $\lambda_j=\varepsilon_j/\epsilon$. The last component in equation (4) measures inefficiency in resource allocation resulting from the deviation of input prices from the value of their marginal products.

Thus, in equation (4), TFP growth is decomposed into i) TP that measures the shift in production frontier over time. It reflects the improvement stemming from innovation and the diffusion of new knowledge and technologies; ii) technical efficiency change ($-du_{it}/dt$) that measures the movement of production towards the known frontier. Changes in quality of capital inputs and improvements in labour force skills, educational attainment of labour force, learning by doing etc. will lead to improvement in technical efficiency; iii) effect of scale change [$(\epsilon-1)\sum\lambda_j\ \dot{x}_{jt}$]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 $\sum(\lambda_j - S_j)\dot{x}_{jt}$.

The last component captures the impact of deviations of inputs' normalized output elasticities from their expenditure shares or, somewhat less clearly, input prices from value of their marginal products [Kumbhakar and Lovell (2000)].

A. 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:

$$Lny_{it}=\beta_0+\beta_L lnL_{it}+\beta_K lnK_{it}+\beta_t t+1/2\beta_{LL}L_{it}^2+1/2\beta_{KK}K_{it}^2+1/2\beta_{tt}t^2+\beta_{LK}lnL_{it}lnK_{it}+\beta_{Lt}L_{it}t+\beta_{Kt}K_{it}t+v_{it}-u_{it} \text{-------} (5)$$

where y_{it}, L_{it} and K_{it} are respectively output, labour input, and capital input of the 2-digit manufacturing industries of petroleum and coal products in the 'i'th state at time 't'. The distribution of technical inefficiency effects, $u_{it,}$ is considered to be non- negative truncation of the normal distribution N(μ, σ^2_u), following Battese & Coelli (1992). It takes the form:

$$u_{it}=\eta_t u_i=u_i exp(-\eta\ [t-T]),\ i=1,\dots,N;\ t=1,\dots,T \text{------------}(6)$$

Here, the unknown parameter η represents the rate of change in technical inefficiency, and the non-negative random variable, u_i, is a measure of 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 organized manufacturing industries with a positive η are likely to improve its level of efficiency over time and vice-versa. A value of η=0 implies no time effect.

Given the estimates of the parameters in equation (5) and (6), the technical 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

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

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

$$TP_{it}=\partial lnf(x_{it,}\beta_{,}t)/\partial t=\beta t+\beta_{tt}t+\beta_{Lt}\ lnL_{it}+\beta_{kt}lnK_{it} \text{---------} (8)$$

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, Coelli, Prasada Rao and Battese (1998) 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

$$TPit= [1+\partial\ lnf(x_{it},\beta,t)\ /\partial t]*[1+\partial\ lnf(x_{it+1,}\beta,t+1)/\partial t+1]^{1/2}-1 \text{--------}(9)$$

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

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

$\varepsilon_L = \partial \ln f(x_{it},\beta,t) / \partial \ln L_{it} = \beta_L + \beta_{LL} \ln L_{it} + \beta_{LK} \ln K_{it} + \beta_{Lt} t$---- (10)

$\varepsilon_K = \partial \ln f(x_{it},\beta,t) / \partial \ln K_{it} = \beta_K + \beta_{KL} \ln L_{it} + \beta_{KK} \ln K_{it} + \beta_{Kt} t$--- (11)

The above equations show the percentage change in output with respect 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:

$\epsilon = \varepsilon_{L+} \varepsilon_K$------- (12)

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).

B. Data and Variables

The study is based on panel data collected from the various issues of Annual Survey of Industries (ASI), Central Statistical Organization (CSO), Ministry of Statistics and Program Implementation, Government of India, New Delhi, for the period 1981-82 to 2010-11. The variables used in this exercise are output and labour and capital inputs.

Deflated value added has been taken as the measure of output. Deflator has been prepared by dividing nominal GDP by Real GDP, the data of which have been obtained from different volumes of NAS. Number of persons engaged is taken as the measure of labour input.

As workers, working proprietors and supervisory/managerial staff/ technicians etc. can affect productivity; number of persons engaged is preferred to number of workers.

Total emoluments divided by total number of persons engaged in production is considered as price of labour input.

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 formation (at constant prices) using the perpetual inventory accumulation method.

The annual rate of depreciation of fixed assets has been taken as 5 per cent (Most of the studies on Indian manufacturing used it at 5% level; a few cases also took it at 1% level).

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

IV. ESTIMATION OF STOCHASTIC PRODUCTION FRONTIER

The maximum likelihood estimates for the parameters of the translog stochastic frontier model, defined by equation (5) and (6), namely,

$\text{Ln}y_{it} = \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_t t + 1/2\beta_{LL} L_{it}^2 + 1/2\beta_{KK} K_{it}^2 + 1/$

$2\beta_{tt} t^2 + \beta_{LK} \ln L_{it} \ln K_{it} + \beta_{Lt} L_{it} t + \beta_{Kt} K_{it} t + (v_{it} - u_{it})$; and

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

are obtained using the program FRONTIER 4.1, in which the variance parameters are expressed in terms of $\gamma = \sigma^2_u / \sigma^2$ and $\sigma^2 = \sigma^2_u + \sigma^2_v$ (Coelli 1996) as reported in Table 4.1. Most of the estimated coefficients of the translog stochastic frontier production functions are found to be statistically significant at the conventional levels.

However, it is widely recognized that under translog specification there may exist multi-collinearity among the interaction and squared terms (Gounder and Xayayong 2004).

As a result certain estimated coefficients are found to be statistically insignificant.

The estimation results (Table 1) show that the estimated value of gamma ($\gamma = \sigma_u^2/\sigma^2$), the ratio of the variance of inefficiency error to variance of total random error in the 2-digit manufacturing industries of petroleum and coal products is 0.48 and it is statistically significant at less than 1% probability level.

This implies that the aforementioned manufacturing industries of fifteen major industrialized states in India and in India as a whole are operating at 48% of their potential output determined by the frontier technology.

So it can be inferred from this result that each year or within a range of years the innovating manufacturing industries of petroleum and coal products keep on or shifting for better technologies;

however, for various reasons, such as incomplete knowledge of the best practice and other institutional factors, they are unable to follow the best practice techniques of the chosen technology.

As a result, the industries fail to achieve 100% technical efficiency and the level of efficiency seems to be more or less at the same percentage level over the year

TABLE 1 PARAMETER ESTIMATES OF THE STOCHASTIC PRODUCTION FRONTIER AND TECHNICAL INEFFICIENCY MODEL IN THE 2-DIGIT MANUFACTURING INDUSTRIES OF PETROLEUM AND COAL PRODUCTS

Variables	Parameters	Coefficients
Constant	β_0	--1.64(1.32)
lnL	B_L	0.11(0.47)
lnK	β_K	1.37***(0.30)
t	β_t	-0.075***(0.032)
lnL^2	β_{LL}	0.094**(0.049)
lnK^2	β_{KK}	-0.017(0.026)
t^2	β_{tt}	-0.003***(0.0004)
lnL*lnK	β_{LK}	-0.103**(0.066)
lnL*t	β_{Lt}	0.00098**(0.0052)
lnK*t	β_{Kt}	0.018***(0.0049)
Sigma squared	σ^2	0.38***(0.102)
Gamma	Υ	0.48***(0.12)
Mu	μ	0.85***(0.18)
Eta	η	-0.0014(0.007)
Log-Likelihood	-327.10	
Standard errors are mentioned in the parenthesis		
***,** & * denote statistical significance at the 1%, 5% and 10% levels, respectively		

Source: Authors' own calculation

A. Tests of Hypotheses

On the basis of the test results (Table 2), we reject the null hypothesis of the traditional Cobb-Douglas functional form in the 2-digit manufacturing industries of petroleum and coal products in India and in its fifteen major industrialized states. Thus, translog production function specification is favoured over the Cobb-Douglas representation in the 2-digit manufacturing industries of petroleum and coal products in the fifteen major industrialized states in India and in India as a whole.

The second test we have conducted in this study consists of testing the null hypothesis that there is no technological change over time.

The test results show that the null hypotheses of 'no technological change over time' are rejected. The third null-hypothesis is that the technological progress is neutral.

However, the translog parameterization of the stochastic frontier model allow for non-neutral technological change.

Now, statistical tests suggest the existence of non-neutral technological change in the data set of these industries.

Fourth, with regard to the case of technical inefficiency effects, we test the null hypotheses of no technical inefficiency effects against the alternatives of the presence of inefficiency effects.

The tests results provide evidences that technical inefficiencies are absent in the 2-digit manufacturing industries of petroleum and coal products in India and in its major industrialized states.

The fifth null-hypothesis, specifying that technical inefficiency effects have half-normal distribution (H_0: μ=0) against truncated normal distribution, is rejected at 5% level of significance.

The sixth null-hypothesis, that technical inefficiency is time-invariant (H_0: η=0) is accepted both at 5% as well as at 1% level of significance.

This implies that technical inefficiency in the organized manufacturing industries of transport equipments is time-invariant in nature as statistical tests suggest.

TABLE II TESTS OF HYPOTHESIS FOR PARAMETERS OF THE DISTRIBUTION OF TECHNICAL INEFFICIENCY EFFECTS AND APPROPRIATENESS OF THE FUNCTIONAL FORM OF 2-DIGIT MANUFACTURING INDUSTRIES OF PETROLEUM AND COAL PRODUCTS

	Log-likelihood Value Test statistics		**Test statistics**	**Critical value**		**Decision**
Null Hypothesis	**$L(H_1)$**	**$L(H_0)$**	**$\lambda = -2[L(H_0)-L(H_1)]$**	**At 1% level**	**At 5% level**	**Reject H_0/ Accept H_0**
Cobb-Douglas production specification H_0: $\beta_{LL}=\beta_{KK}=\beta_{LK}=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$	-327.10	-363.89	73.58	16.81	12.59	Reject H_0
No technological change H_0: $\beta_t=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$	-327.10	-368.35	82.50	13.28	9.49	Reject H_0
Neutral technological change H_0: $\beta_{Lt}=\beta_{Kt}=0$	-327.10	-344.15	34.10	9.21	5.99	Reject H_0
No technical inefficiency H_0: $\Upsilon=\mu=\eta=0$	-327.10	-329.34	4.48	11.34	7.81	Accept H_0
Half normal distribution of technical inefficiency H_0: μ=0	-327.10	-329.32	4.44	6.63	3.84	Reject H_0 at 5% level
Time invariant technical inefficiency H_0: η=0	-327.10	-327.10	0	6.63	3.84	Accept H_0

B. *Estimation and Decomposition of TFPG*

Based on the translog production function estimates shown in Table 1 we derived the following three measures: rates of technological progress (TP), economic scale effects (SC) and allocation efficiency effects (AEC); where technical efficiency effects (TEC) remain absent and/or they are time invariant in nature as statistical tests (Table 2) suggest.

The aforesaid three measures are then added to obtain total factor productivity growth (TFPG). Because the translog specification is used, the performance of these measures varies depending on states and years. For the three sources of the TFP growth, Tables (3a) – (3p) in the Appendix show that the rate of technological progress (TP) is the major contributing factor to total factor productivity growth (TFPG) of the 2-digit manufacturing industries of petroleum and coal products.

Again, TFPG of these industries in almost all the states under study including that in All-India have declined during the post reform period and the decline in TFPG of these industries during the post-reform period is mainly accounted for by the decline in TP of the same during that period. Economic scale effects (SC) and

allocation efficiency effects (AEC) in almost all the states under study are found to be negligible and in many states they are even found to be negative although

they have increased significantly in many states during the post-reform period. In spite of that their combined estimates are still far below the estimates of technological progress during that period.

These findings clears that although factor accumulation may lead to the TFP growth through increasing returns to scale or through economic utilization of resources, the most important factor of TFP growth of the 2-digit manufacturing industries of petroleum and coal products is the technological progress.

So it is clear from Table 3a to Table 3p in the Appendix that TFP growth rates in the manufacturing industries of petroleum and coal products in almost all the states in India as well as those in All-India have declined during the post-reform period and the decline in TFPG of the aforementioned industries of the states under study during the post-reform period is mainly responsible for the decline in TP of the same during that period. Further, considering two decades of the post-reform period (1981-82 to 1990-91 and 1991-92 to 2010-11) we see that rates of technological progress (TP) became lower during the last half of the post-reform period (1991-92 to 2010-11) compared to those of the first half (1981-82 to 1990-91) whereas rates scale effects (SC) and allocation efficiency effects (AEC) became lower during the first half of the post-reform period (1981-82 to 1990-91). Although rates of TFPG became lower during the last half of the post-reform period.

Table 3a to Table 3p in the Appendix show that Bihar (4.30%) is the only state among 15 major industrialized states in India and India as a whole (4.76%) have achieved more than 4 percent annual average growth rates of TFPG in the organized manufacturing industries of petroleum and coal products during the entire study period (1981-82 to 2010-11).

Total four states out of these 15 states have achieved average annual growth rate of TFPG of the same in the range of 4 percent to 2 percent; three states have achieved average annual growth rate of TFPG in the range of 2 percent to 0 percent and seven states have experienced negative average annual growth rates of TFPG of the same. So far as the shares in the average annual growth rates of TFPG of the three sources of TFPG are concerned, technological progress (TP) are found to have the maximum share in almost all the states under study and in India as a whole during the entire study period.

The share of the other sources of total factor productivity growth (TFPG), namely, scale effect (SC) and allocation efficiency effect (AEC) remain very insignificant (negative in many cases); whereas, in the case of TEC its share has been remaining absent in all the states under study including those in All-India in all through the years as it is suggested by statistical tests of hypothesis (Table 2).

So what we see is that the average annual growth rate of TFPG of the manufacturing industries of petroleum and coal products in India and in its 15 major industrialized states during 1981-82 to 2010-11 is mainly accounted for by only one factor-the rate of technological progress (TP).

The scale effects (SCs) and allocation efficiency effects (AECs) are very negligible in most of the states under study and their effects have been negative too in many states under study whereas technical efficiency effects of the same remain absent in all the states and in All-India too as statistical tests (Table II) suggest.

A comparison of the performance of TFPG of the 2-digit manufacturing industries of petroleum and coal products and the share of the three sources of TFPG during the pre- and post-reform periods shows that only seven states including All-India have achieved positive growth rates of TFPG (more than 0 percent) during the post-reform period (Table 3a to Table 3p in the Appendix).

As in the case of the entire study period (1981-82 to 2010-11), during the pre-and post-reform periods, the share of technological progress has been greater than the shares of the scale effects (SC) and allocation efficiency effects (AEC) in most of the states under study whereas the effect technical efficiency (TEC) has been remain unchanged and/or it has no effect at all as statistical tests suggest. It is only in Bihar AEC exceeds TP both in the entire study period and in the post-reform period and SC exceeds TP in

Haryana, Madhya Pradesh and Punjab during the same period of time.

A further division of the post-reform period into two sub-periods of 1991-92 to 2000-01 and 2001-02 to 2010-11 is made to estimate the relative contribution of the sources of TFPG of the said industries during these two sub-periods of one decade each (Table 3a to Table 3p in the Appendix). From Table 3a to Table 3p in the Appendix we see that 8 states and India as a whole have registered higher growth rates of TFP (more than 5 percent) during the first half of the post-reform period while not a single state registered more than 2 percent growth rates of TFP during the second half of the post-reform period.

However, in the first half of the post-reform period the contribution of technological progress (TP) has been higher in most of the states under study. On the other hand, the contributions of scale effects (SC) and allocation efficiency effects (AEC) have been improved during the second half of the post-reform period though they are very negligible while technical efficiency effect remains unchanged and/or it has no contribution at all as it was suggested by statistical tests of hypotheses.

V. SUMMARIES AND CONCLUSION

The study examines the sources of TFPG of the 2-digit manufacturing industries of petroleum and coal products in fifteen major industrialized states in India as well as in all-India during the period from 1981-82 to 2010-11, for the entire period, pre-reform period (1981-82 to 1990-91), post-reform period (1991-92 to 2010-11) and also for two decades of the post-reform period (1990-91 to 2000-01 and 2001-02 to 2010-11) using translog stochastic production frontier approach.

The methodology involves decomposition of the sources of TFPG into technological progress, technical efficiency changes, allocation efficiency changes and scale effects. The study shows that the growth rates of TFP in the manufacture of petroleum and coal products in the major industrialized states in India as well as in All-India have declined during the post-reform period and the decline in TFPG is mainly responsible for the decline in TP of the same during that period.

This is further because the contribution of scale effect and allocation efficiency effect to TFPG of the 2-digit industries of petroleum and coal products in the major industrialized states in India has become very negligible. Although, it is found that during the second half of the post-reform period the scale effects and allocation efficiency effects in almost all the states under study as well as in All-India have improved.

So it can be said that the manufacturing industries of different states under study including those in All-India have benefitted from economies of scale. However, their estimates are still far below the estimates of other components of TFPG both in the pre-and the post-reform periods. Thus, although factor accumulation may have led to the TFP growth through increasing returns to scale, TFPG in the 2-digit manufacturing industries of petroleum and coal products in almost all the states under study have declined during the post-reform period.

Further, the allocation efficiency component shows that resource allocation in the same in almost all the states under study have been made more efficiently during the post-reform period. This implies that deregulation of the economy during the post-reform period has reduced the price distortion measured by the gap between price and marginal cost of the 2-digit manufacturing industries in major industrialized states in India as well as those in All-India.

However, as the declining effect of technological progress of the 2-digit industries of petroleum and coal products offset the combined rising effect of AEC and SC of the same during the post-reform period the TFPG of the 2-digit industries of the petroleum and coal products declined during that period.However, the measures of TFPG components of the 2-digit industries of the petroleum and coal products not only provide more insights and better understanding of the dynamic nature of the production process, but also have important policy implications. Policy action intended to improve TFP growth rate might be misdirected if they focus on accelerating the rate of innovation in circumstances where the low rate of TFP growth is brought about by suboptimal size of the firms and poor allocation resources (allocation inefficiency), which really happened in the case of Indian manufacturing sector in general. A thorough examination of industrial policy resolutions reveals that the importance and contribution of efficiency in industrial growth has been neglected or given less priority in the framework of industrial strategy.In this context, the governments should take some policy initiatives to improve productive efficiency of the 2-digit manufacturing industries of petroleum and coal products. Once efficiency increases, it enhances competitiveness by realizing the potential growth of productivity.

APPENDIX

TABLE III A: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN ANDHRA PRADESH

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	2.56	0.76	-0.72	2.60
Pre-reform Period (1981-82 to 1990-91)	7.31	-0.22	-1.91	5.18
Post-reform Period (1991-92 to 2010-11)	0.18	1.24	-0.12	1.30
Post-reform Period: Decade 1 (1991-92 to 2000-01)	2.05	0.49	-0.85	1.69
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-1.69	2.00	0.60	0.91

TABLE III B: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN ASSAM

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	1.42	-0.91	-0.89	-0.38
Pre-reform Period (1981-82 to 1990-91)	4.97	-2.06	-1.28	1.63
Post-reform Period (1991-92 to 2010-11)	-0.35	-0.33	-0.70	-1.38
Post-reform Period: Decade 1 (1991-92 to 2000-01)	1.13	-0.01	1.39	2.51
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-1.84	-0.66	-2.78	-5.28

TABLE III C: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN BIHAR

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	1.52	0.35	2.43	4.30
Pre-reform Period (1981-82 to 1990-91)	6.63	0.25	4.33	11.21
Post-reform Period (1991-92 to 2010-11)	-1.03	0.40	1.48	0.85
Post-reform Period: Decade 1 (1991-92 to 2000-01)	0.67	0.26	1.01	1.94
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-2.74	0.55	1.95	-0.24

TABLE III D: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN GUJARAT

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	4.23	-0.46	-3.18	0.59
Pre-reform Period (1981-82 to 1990-91)	6.74	0.15	-0.41	6.48
Post-reform Period (1991-92 to 2010-11)	2.98	-0.77	-4.57	-2.36
Post-reform Period: Decade 1 (1991-92 to 2000-01)	3.75	-0.02	-3.59	0.14
Post-reform Period: Decade 2 (2001-02 to 2010-11)	2.21	-1.51	-5.55	-4.85

TABLE III E: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN HARYANA

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	-0.51	1.37	-0.26	0.60
Pre-reform Period (1981-82 to 1990-91)	3.81	0.94	-0.22	4.53
Post-reform Period (1991-92 to 2010-11)	-2.68	1.59	-0.27	-1.36
Post-reform Period: Decade 1 (1991-92 to 2000-01)	-0.30	1.20	-1.10	-0.20
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-5.05	1.98	0.57	-2.50

TABLE III F: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN KARNATAKA

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	1.89	0.29	-3.94	-1.76
Pre-reform Period (1981-82 to 1990-91)	4.90	0.27	0.29	5.46
Post-reform Period (1991-92 to 2010-11)	0.38	0.30	-6.06	-5.38
Post-reform Period: Decade 1 (1991-92 to 2000-01)	1.84	-0.29	-13.80	-12.25
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-1.10	0.88	1.65	1.43

TABLE III G: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN KERALA

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	1.94	0.63	-1.19	1.38
Pre-reform Period (1981-82 to 1990-91)	6.43	-0.13	-2.80	3.50
Post-reform Period (1991-92 to 2010-11)	-0.30	1.01	-0.38	0.33
Post-reform Period: Decade 1 (1991-92 to 2000-01)	1.83	0.72	-1.73	0.82
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-2.43	1.31	0.97	-0.15

TABLE III H: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN MADHYA PRADESH

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	0.45	1.47	-3.05	-1.13
Pre-reform Period (1981-82 to 1990-91)	2.75	1.39	0.43	4.57
Post-reform Period (1991-92 to 2010-11)	-0.70	1.51	-4.79	-3.98
Post-reform Period: Decade 1 (1991-92 to 2000-01)	1.65	0.58	-3.81	-1.58
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-3.05	2.44	-5.77	-6.38

TABLE III I: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN MAHARASHTRA

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	4.43	0.13	-1.99	2.57
Pre-reform Period (1981-82 to 1990-91)	8.44	-0.01	-3.24	5.19
Post-reform Period (1991-92 to 2010-11)	2.42	0.19	-1.36	1.25
Post-reform Period: Decade 1 (1991-92 to 2000-01)	4.63	-0.15	-2.58	1.90
Post-reform Period: Decade 2 (2001-02 to 2010-11)	0.22	0.54	-0.14	0.62

ABLE III J: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN ODISHA

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	-2.35	-0.84	-4.11	-7.30
Pre-reform Period (1981-82 to 1990-91)	0.21	-4.28	-10.5	-14.6
Post-reform Period (1991-92 to 2010-11)	-3.63	0.88	-0.90	-3.65
Post-reform Period: Decade 1 (1991-92 to 2000-01)	-1.31	0.60	-3.07	-3.77
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-5.96	1.16	1.28	-3.52

TABLE III K: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN PUNJAB

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	-1.92	1.60	-0.48	-0.80
Pre-reform Period (1981-82 to 1990-91)	2.33	3.06	-0.16	5.23
Post-reform Period (1991-92 to 2010-11)	-4.04	0.86	-0.63	-3.81
Post-reform Period: Decade 1 (1991-92 to 2000-01)	-1.80	1.15	-0.07	-0.72
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-6.28	0.57	-1.18	-6.89

TABLE III L: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN RAJASTHAN

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	0.25	-1.50	-2.11	-3.36
Pre-reform Period (1981-82 to 1990-91)	4.62	-6.29	-4.46	-6.13
Post-reform Period (1991-92 to 2010-11)	-1.94	0.90	-0.94	-1.98
Post-reform Period: Decade 1 (1991-92 to 2000-01)	0.36	0.33	-1.86	-1.17
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-4.23	1.47	-0.02	-2.78

TABLE III M: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN TAMIL NADU

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	3.06	0.50	-0.95	2.61
Pre-reform Period (1981-82 to 1990-91)	7.32	-0.10	-1.19	6.03
Post-reform Period (1991-92 to 2010-11)	0.93	0.81	-0.82	0.92
Post-reform Period: Decade 1 (1991-92 to 2000-01)	3.16	-0.25	-1.49	1.42
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-1.30	1.86	-0.16	0.40

TABLE III N: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN UTTAR PRADESH

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	3.69	0.19	-7.08	-3.20
Pre-reform Period (1981-82 to 1990-91)	3.59	-0.13	-12.40	-8.94
Post-reform Period (1991-92 to 2010-11)	3.74	0.36	-4.43	-0.34
Post-reform Period: Decade 1 (1991-92 to 2000-01)	3.76	-0.21	-10.70	-7.15
Post-reform Period: Decade 2 (2001-02 to 2010-11)	3.71	0.92	1.86	6.49

TABLE III O: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN WEST BENGAL

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	2.10	0.17	0.25	2.52
Pre-reform Period (1981-82 to 1990-91)	6.25	0.08	-0.25	6.08
Post-reform Period (1991-92 to 2010-11)	0.02	0.22	0.50	0.74
Post-reform Period: Decade 1 (1991-92 to 2000-01)	1.99	-0.11	0.11	1.99
Post-reform Period: Decade 2 (2001-02 to 2010-11)	-2.00	0.55	0.88	-0.53

TABLE III P: AVERAGE ANNUAL RATES OF TP, SC, AEC AND TFPG OF THE MANUFACTURE OF PETROLEUM AND COAL PRODUCTS IN INDIA

Study Period	TP	SC	AEC	TFPG
Entire Study Period (1981-82 to 2010-11)	8.19	0.18	-3.61	4.76
Pre-reform Period (1981-82 to 1990-91)	12.80	0.51	-1.55	11.76
Post-reform Period (1991-92 to 2010-11)	5.88	0.02	-4.63	1.27
Post-reform Period: Decade 1 (1991-92 to 2000-01)	7.65	-0.10	-6.71	0.84
Post-reform Period: Decade 2 (2001-02 to 2010-11)	4.11	0.11	-2.55	1.66

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