MEASUREMENT OF PRODUCTIVITY GROWTH – A PARAMETRIC APPROACH

By

Padma Saravanan

MEASUREMENT OF PRODUCTIVITY GROWTH –
A PARAMETRIC APPROACH

1. INTRODUCTION

In the present era of increasing globalization and easy access to modern communication technology, firm in all countries are under pressure to improve their production efficiency in order to survive and thrive in the face of competition from newly emerging domestic firms on the one hand and foreign competition on the other. This is especially true in the case of India, which initiated major economic reform in 1991 in an attempt to make a systematic shift toward an open economy along with privatization of a large segment of its economy. These reforms were phased in over a number of years and many aspects of the reforms are only recently being implemented Ahluwalia [1]. The removal of barriers to entry has opened up the economy to international market forces which, coupled with rising economic and social aspirations of the population, has led to the rapid emergence of a highly competitive environment, especially in the industrial sector. This has emphasized the importance of continuous improvement in productivity and efficiency, particularly if India is to achieve the high growth rate target set for the industrial sector.

As found in most of the empirical works, productivity growth plays a major role in enhancing economic growth as well as the standard of living. Efficiency gains and productivity improvements in the industrial sector are among the most important factors for successful economic reforms. At firms, and industrial level, productivity positively influences profitability, reduction of cost and price, which ultimately strengthens the competitiveness of firms and industries in the global competitive world. It is observed that cross-country disparities in real incomes, growth rates and standard of living have been attributed to differences in productivity performance. Therefore, total factor

productivity growth is considered as an indicator of sustained economic growth and improvement in the standard of living. It is a well recognized fact that countries with poor performance in factor productivity growth would loose international competitiveness and thus, do not fully benefit from globalization. On the contrary, a higher level of productivity growth may result in lower product prices, better remuneration and working conditions to the employees, better returns to investors, adequate surplus available for expansion and modernization, besides giving a positive edge to these firms in the international market.

Although liberalization has been implemented effectively at the center, there has been considerable variation in the speed and extent of implementation of the reform measures across the different states, which has exacerbated regional imbalances. For the overall industrial sector to surge ahead it is very important to address the regional problems. In view of this, an analysis of the regional variation in productivity growth across the states is important. Total Factor Productivity (TFP) is the measure of performance of a productive unit. TFP may be defined as an index of change in output net of changes in inputs over the same period. A series of TFP growth is calculated over a period of time and a suitable index is constructed to get the total factor productivity of a production unit. Productivity has been one of the most popular areas of applied economic research as it is based on the well-defined analytical framework of the standard economic theory of production.

2. REVIEW OF PREVIOUS STUDIES

The recent literature on productivity in India, such as, Aghion et al [2], Das [3], and Topalova [4], attempts to examine the relationship, if any, between economic reforms and growth rate of productivity in India. However, the studies dealing with productivity at regional (state) levels have been rather few. A spatial mapping of growth process and productivity movement is important. Hence the focus of the study is on the analysis of inter-state differences in productivity levels and growth rates for the period during 1980-81 to 2005-06.

3. DATA AND METHODOLOGY

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 1980-81 to 2005-06. In this study, output is measured in gross value added, labour is measured in terms of the total number of persons employed and capital is measured in fixed capital.

4. MODEL SPECIFICATION

Total Factor Productivity is defined as the ratio of weighted sum of output to the weighted some of inputs. Under TFP approach there are two types of estimation namely: A non-parametric approach and a parametric production function approach.

4.1. PARAMETRIC APPROACH

The parametric approach requires the determination of a specific functional form such as a regression equation or a production function, which relates the independent variables to the dependent variables. The functional form thus selected requires specific assumptions about the error terms and some restrictions. The objective is to attain by optimization a single regression plane through the entire data. This study adopts parametric approach.

5. MEASURES OF TOTAL FACTOR PRODUCTIVITY GROWTH

Empirical estimation of different total factor productivity indexes are based on different weighting schemes**.** So, each measure differs from one another due to the fundamental assumptions involved [5]. In most empirical studies either the Kendrick index or the Solow index are frequently used. In some resent studies, we observe the use of the Divisia index based on the translog production function.

5.1 KENDRICK INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH

This measure of total factor productivity was employed by Kendrick [6] in order to study the TFPG in American industries. Kendrick's measure is based on a linear production function that confines itself to labour and capital as factor inputs.

It is assumed that there is one homogenous output denoted by "Y" and there are two factors of production viz, capital denoted by 'K' and labour denoted by 'L'. Further, 'w0' and 'r0' are assumed to denote the factor rewards of labour and capital in the base year of the study. Then the Kendrick index of TFP for the year't' may be written as

$$A_t = \frac{Y_t}{w_o L_t + r_o K_t} \qquad \ldots\ldots (1)$$

This formula can be adjusted to take into account more than two factors of production. The assumptions underlying this index is constant returns to scale, perfect competition and payment to factors strictly according to their marginal product(i.e.) that total earning of labour and capital in the base year will exactly equal to the out put of the year. This means that A_t (total factor productivity) in the base year will be equal to unity by definition. The Kendrick index may be interpreted as the ratio of actual output to the output which would have resulted from increased inputs in the absence of technological; change. While the Kendrick index is easy to calculate and understand, it suffers from the assumption that the underlying production function will be linier in nature and that it does not allow for the possible diminishing marginal productivity of factors.

5.2 SOLOW INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH

Solow's [7] index uses the Cobb-Douglas production function with the assumption s of constant returns to scale, autonomous Hick's neutral technical progress and the factor payments being equal to their marginal products. The production function used is

X=A (t) F (K, L) …… (2)

Where the X represents capital, labour and output respectively and multiplicative factor A(t)measures the cumulated effects of shifts in the function. Taking the total differential of the equation (2) with respect to time and dividing by 'X'yeilds

$$\frac{\dot{X}}{X}=\frac{\dot{A}}{A}+\mathrm{A}\frac{fk}{Kx}+A\frac{fL}{Lx} \qquad \text{…….. (3)}$$

Where X is physical units of the output and the dots are time derivatives, for example $x=\partial X / \partial t$. If we state that $\partial X / \partial t$ = q/p, i.e, the marginal products of capital is equal to the rental value of capital (q).

$\partial X / \partial L$ =w/p …….. (4)

Where 'w' is the wage rate and 'p'is the price of output per unit. Therefore,

$\partial X / \partial K$ *K/X=Wc …… (5)

Where Wc is the relative share of the capital.

$\partial X / \partial L$ *L/X=Wn ……. (6)

Where Wn is the relative share of labour. Now substituting this in to the function

$V = AL^{\alpha} K^{\beta}$ we get

X/L=x, K/L= k and W_n=1-W_c, $\frac{\dot{X}}{X} = \frac{\dot{A}}{A} + W_c \frac{K}{K}$

$$\frac{\dot{X}}{X} = \frac{\dot{A}}{A} + W_C \frac{\dot{K}}{K} + W_n \frac{\dot{L}}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

OR

$$\frac{\Delta X_t}{X_t} = \frac{\Delta A_t}{A_t} + W_c \frac{\Delta K_t}{K_t} + W_n \frac{\Delta L_t}{L_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Where Δ s are the discrete approximation to time derivatives. Equation (7) is the basic equation with which it is possible to obtain time series concept of $\Delta A_t/A_t$, which is a measure of technological change. Now, for each year At can be calculated provided the other terms in equation (7) are evaluated. Solow simplifies his expression by dividing it by 'L'. If we take value added per man day (V/L) as an index of labour productivity instead of output per man day (X/L) then the expression would be:

$$\frac{\Delta(V/L)_t}{(V/L)_t} = \frac{\Delta A_t}{A_t} + \beta \frac{\Delta(K/L)_t}{(K/L)_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Hence, Solow has assumed that there is a fixed share of capital (β) in the total value added per man day. Hence, β coefficient has been calculated by fitting the function.

$$LNV/L = \alpha.\beta LN(K/L) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Thus, β will be the share of capital. Now rearranging terms, we get the following expression.

$$\frac{\Delta A_t}{A_t} = \frac{\Delta (V/L)_t}{(V/L)_t} - \beta \frac{\Delta (K/L)_t}{(K/L)_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

From the estimated series of ΔAt/At, using the following procedure we can derive the total factor productivity growth trend viz., At.

$$A_{(t+1)} = A_t \left[1 + \frac{\Delta A_t}{A_t} \right]$$

Though, Solow index is based on the restrictive assumption of unitary elasticity of substitution, it is not a serious drawback. Nelson [8] has shown non-unitary elasticity of substitution is unlikely to make significant difference in the estimates of total factor productivity. It is interesting to note that under the assumption of competitive equilibrium, the Solow index and Kendrick index are equivalent for small changes in output and inputs [9].

5.3 DIVISIA INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH

The need for using the Divisia index was spelt out by Solow [10] and Jorgensen and Griliches [11]. It was on the strength that the rates of growth of the Divisia indexes of prices and quantities add up to the rate of growth of the value added (factor reversal test) and that such indexes are symmetric in different directions of time(time reversal test). Divisia indexes also have the reproductive property that" a divisia index of divisia index is a divisia index of the components". a discrete version of the continuous Divisia index is the translog index.translog index numbers are symmetric in data of different time periods and also satisfy the factor reversal test approximately. But, they do not have the reproductive property [12]. The translog index of technological change is based on a

translog production function characterized by constant returns to scale. It allows for variable elasticity of substitution and does not assume Hicks' neutrality.

Consider an aggregate production function with two factors of production

$$Y= F(K,L,T) \quad \ldots\ldots\ldots\ldots \quad \ldots\ldots\ldots\ldots\ldots\ldots .. .(12)$$

Where Y denotes aggregate output, "K" aggregate capital, L aggargate labour and T time. It is assumed that F is countinues, twice differentiable with a characteristic feature of constant returns to scale. These aggregates are taken as functions of their components.

$$Y=Y(Y_1,Y_2,Y_3,\ldots\ldots\ldots\ldots Y_m) \quad \ldots\ldots\ldots\ldots\ldots\ldots(13)$$

$$K=K(K_1,K_2,K_3,\ldots\ldots\ldots\ldots K_n) \quad \ldots\ldots\ldots\ldots\ldots..(14)$$

$$L = L(L_1,L_2,L_3\ldots\ldots\ldots\ldots L_q) \quad \ldots\ldots\ldots\ldots\ldots(15)$$

Corresponding to them, there are 'm output prices, 'n' capital prices and 'q' labour prices denoted respectively.

$P_1,P_2,\ldots,P_m$; $r_1,r_2 \ldots, r_n$; $w_1,w_2,\ldots\ldots\ldots w_q$ Corresponding aggregate prices are denoted by p,r,w. Under the assumption of perfect competition and profit maximization , the condition of producer's equilibrium requires the shares of the factors be equal to their elasticities , so that , we get:

$$V_k = r_k/Py = logY/logK \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

$$V_L = w_l/ Py = logY/logL \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .(17)$$

Because of constant returns Vk+VL =1, similarly, for individual components the conditions of producers equilibrium require,

$$SY_i = P_iY_i / PY = log\ Y/logY_i,\ i= 1\ldots\ldots\ldots m \quad \ldots\ldots\ldots .. \quad (18)$$

$$Sk_j = R_jK_j /RK = log\ K/\ logK_j,\ j= 1\ldots\ldots\ldots n \quad . \ldots\ldots .. (19)$$

$SL_u = W_uL_u/WL = \log L/\log L_u, u = 1 \ldots\ldots \quad q$.(20)

SY_i is the share of ith output components in aggragate output, similarly, SKj and SLu are the shares of the jth capital output and uth labour input respectively. Linear homogeneity requires

$SY_i = SK_j = SL_u = 1$

Differenticiation equation (12) with respect to time and re arranging termes , we obtain,

$$\frac{d\log Y}{dT} = V_k \frac{d\log K}{dT} + V_L \frac{d\log L}{dT} + V_T \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (21)$$

The expression VT is called the Divisia quantity index of technological change. It should be noted that in the above expression.

$$\frac{d\log Y}{dT} = SY_i \frac{d\log Y_i}{dT} . \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots \qquad \ldots.. (22)$$

$$\frac{d\log K}{dT} = SK_j \frac{d\log K_j}{dT} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad .... (23)$$

$$\frac{d\log L}{dT} = SL_u \frac{d\log L_u}{dT} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad \ldots(24)$$

Thus, a weighted average growth rate of individual components gives the growth rate for the aggregate output. These are respectively called the Divisia quantity index of output, capital and labour.

On the price side, the assumption of constant returns to scale, perfect competition and profit maximization require that the prices of output, capital and labour be consistent with the following equation.

$PY = rK + wL \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots \qquad (25)$

Given this equation we can express ‘p’ as a function of r, w and T

$P = f(r, w, T) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad .(26)$

This is referred to as the price function. From the point of view of the price function, technological change is defined as

$$V_T = \frac{\log P}{T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad . \quad .(27)$$

This can be written as

$$\frac{d \log P}{dT} = V_k \frac{d \log r}{dT} + V_L \frac{d \log w}{dT} + V_T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

This gives the Divisia price index of technological change.

For application to data at discrete point of time, the Translog index is used. This Translog production function (22) is typically written as

$$\text{LogY} = \alpha_o + \alpha_k \text{logK} + \alpha_L \text{logL} + \alpha_T(T) + {}_{1/2}\beta_{kk}(\text{logk})^2 + \beta_{kL}(\text{logK})^2 + 1/2\beta_{LL}(\text{logL})^2$$

$$+\beta_{kT}(\text{logK})T + \beta_{LT}(\text{logL})T + {}_{1/2}\beta_{TT}(T)^2 \quad . \quad (29)$$

constent returns requires

$$\alpha_K + \alpha_L = 1;\ \beta_{kk} + \beta_{kL} = 0;\ \beta_{kL} + \beta_{LL} = 0 \quad (30)$$

Corresponding to equation (23) we get here

$$\Delta\text{logY} = V_Y(\Delta\log K) + V_L(\Delta\text{logL}) + V_T \quad (31)$$

Where,

$$\text{logY} = \text{logY}_{(T)} - \text{logY}_{(T-1)} \quad (32)$$

$$\text{logK} = \text{logK}_{(T)} - \text{logK}_{(T-1)} \quad (33)$$

$$\text{logL} = \text{logL}_{(T)} - \text{logL}_{(T-1)} \quad (34)$$

and

$$V_K = ½ [V_{K(T)} + V_{K(T-1)}] \quad (35)$$

$$V_L = ½ [V_{L(T)} + V_{L(T-1)}] \quad (36)$$

This expression for V_T in equation (31) is termed as the average translog quantity index of technological change.

6. RESUTLS AND DISCUSSION

6.1 KENDRICK INDEX

The empirical estimates of Kendrick index of TFPG for the industrial sector of select 16 states of the Indian union are portrayed in **table 1.** The average contribution of the Kendrick index of total factor productivity to output growth during 1980s was found to be greater than the base year value of 100.00 in 15 of the sixteen states in reference. These include Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. The estimates of Kendrick index for the individual states in the 1990s were greater than the base year value of 100.00 in all of the 16 states in reference. In Bihar the TFP assumed relatively higher rates of contribution to output growth in 1990s while in the 1980s the productivity rates were comparatively lower. The state which had total factor productivity growth rate less than the base year value 100.00 in 1980s includes Himachal Pradesh. A closer examination reveals that all the states except Assam, the contribution of output growth have registered an improvement in the 1990s. The state of Assam exhibited negative average compounded Total Factor Productivity Growth (TFPG) during the reference period 1980-81 to 2005-06. This shows that improvement in augmenting technical efficiency did not act as a source of output growth in this state. For the period as a whole, the picture that emerges is more similar to that of 90s. In the following 14 states viz. Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal the TFP rates were more than unity in both 80s as well as 90s.

The cross-section characteristic of Kendrick index of TFPG for the period 1980-81 to 2005-06 reveals the following picture. The period's average mean of TFP growth is estimated from the period's mean of the individual states. The period's average rate of TFP was found to be greater than the base year value of 100.00 in all of the study period. During the year 2004-05 the TFP rate has been marked with a high magnitude of 218.64. In general, the present study finds a positive TFP trend characterizing the 16 states of Indian industrial sector with magnitude of 2.57 per cent.

6.2. SOLOW INDEX

An analysis of TFPG is attempted by employing Solow's measure to trace the nature and characteristics of output growth for the 16 states of Indian industrial sector. The empirical estimates of Solow index of TFPG are presented in **table 2.** The average contribution of TFPG to output growth during the 1980's was greater than the base year value of 100.00 in six of the 16 states in reference. These states include Andhra Pradesh, Assam, Bihar, Gujarat, Haryana and Karnataka. Out of these 6 states, only two states viz. Andhra Pradesh and Haryana, the Solow index was greater than the base year value of 100.00 in the 1990's as well. Further examination reveals that all states except Andhra Pradesh, Uttar Pradesh and West Bengal the contribution of output growth has declined in the 90's as against the 80's.

The states which had total factor productivity rates less than the base year value of 100.00 in the 1980's as well as 1990's include Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu and West Bengal. When compared to the 1980's, the contribution of TFP to output growth has declined in 81.00 per cent (13 states) of the states during the 1990's. The state of Himachal Pradesh was registered a low magnitude of 43.88 per cent in 1990's. Most of the states, viz. 13 out of 16 states exhibited negative annual compound growth rate in TFP for the period as a whole. This shows that improvement in augmenting technical efficiency did not act as source of output growth in these states during the reference period. These states include Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan and Tamil Nadu.

The cross-section characteristic of Solow index of TFPG for the period 1980-81 to 2005-06 revealed the following picture. The period's average TFP growth is estimated from the period's mean of the individual states. The period's average rate of TFP was more than the base year rate of 100.00 only in three of the 25 years in the study period. In specific terms, the initial years of 1980's i.e. 1981-82, 1982-83 and 1983-84 were associated with TFP rates greater than 100.00. The TFP rates across the different states were characterized by very low magnitude in a majority of the years in the study. In general, the present study finds a negative TFP trend characterizing the magnitude with around -0.69 per cent in the 16 states of Indian industrial sector.

6.3. DIVISIA INDEX

The empirical estimates of Divisia index of TFPG for the 16 states of Indian industrial sector are presented in **table 3.** The average contribution of Divisia index of total factor productivity to output growth during the 1980's was found to be greater than the base year of 100.00 in six of the 16 states in reference. These include Andhra Pradesh, Assam, Bihar, Himachal Pradesh, Orissa and Uttar Pradesh. Five states continued to have TFP rates greater than 100.00 in the 1990's as well. They include Himachal Pradesh, Orissa, Punjab, Rajasthan and Uttar Pradesh. A closer examination reveals that, in the states of Himachal Pradesh, Kerala, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh the contribution of output growth have registered improvement in 1990's.

The states, which had total factor productivity less than the base year value of 100.00 in the 1980's as well as in 1990's are Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh Maharashtra, Tamil Nadu and West Bengal. The state of Kerala having lesser TFP rates in 1980's and shown an improvement in 1990's. In 10 out of the 16 states during the study period 1980-81 to 2005-06, exhibited a negative average compounded total factor productivity growth. The ten states are Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharshtra, Uttar Pradesh and

West Bengal. This shows that improvement in augmenting technical efficiency did not act as a source of output growth in these states.

The cross section characteristics of Divisia index of TFPG for the period 1980-81 to 2005-06 reveals the following. The period's average mean of TFP growth is estimated from the period's mean of the individual states. The period's average rate of TFP was found greater than the base year value of 100.00 in the following years: 1981-82, 1988-89 to 1992-93, 1995-96 to 1997-98, and 2005-06. Compared to 1980's, the TFP growth marked slightly higher rates of growth in the 1990's. In general the study finds a negative TFP trend characterizing the 16 states of Indian industrial sector with magnitude of -0.15 per cent.

7. SUMMARY AND CONCLUSION

An analysis of the behavioural characteristics of TFP across states provides useful scope to understand how efficient use of technology has led to growth in output in the Indian industrial sector. In the present study we have provided an elaborate analytical discussion as to the contribution of total factor productivity to output expansion in the 16 states of Indian industrial sector for the period 1980-81 to 2005-06. For the purpose of empirical estimation, we have used Kendrick Solow and Divisia Index of total factor productivity indexes. In the following section, a summary of the important conclusion emerging from the analysis is presented.

The empirical estimates of Kendrick index of TFPG for the 16 states of Indian industrial sector broadly indicating that the total factor productivity to output growth was greater than the base year value of 100.00 in all the 16 states in reference. In our study all the select states, except the state of Assam, exhibited positive rates of TFP growth characterizing efficient use of existing technology paving way for higher output growth.

The estimates of Solow index showed that the average contribution of TFP to output growth was greater than the base year value of 100.00 in Andhra Pradesh, Haryana and Uttar Pradesh. On the whole, only in the states of Andhra Pradesh, Uttar Pradesh and

West Bengal have obtained positive annual compound growth rate in TFP for the study period.

The Divisia index of TFPG for the 16 states of Indian industrial sector showed that the average contribution of TFP to output growth was greater than base year value of 100.00 in Himachal Pradesh, Orissa, Punjab, Rajasthan and Uttar Pradesh. In the above states, the TFP registered only marginal increase in output growth. In the remaining 12 states the TFP did not act as a source of output growth.

8. CONCLUSION

The estimated of total factor productivity while using the Kendrick index has generally implied better output growth rates than Solow's and Divisia index. Further we could also find the TFP growth in the 1990s having slightly higher influence on the process of output growth vis-à-vis the 1980s. This implies that a liberalized economic regime has been favourable for the Indian industrial sector to harness their strength in improving their technical efficiency.

REFERENCES

1. Ahluwalia, (2002), Economic Reforms in India since 1991: Has Gradualism Worked? *Journal of Economic Perspectives,* 16 (3) 67-88.

2. Aghion, and et al (2003), The Unequal Effects of Liberalization Theory and Evidence from India.

3. Das, (2003), Manufacturing Productivity Under Varying Trade Regimes: India In The 1980s And 1990s, Working Paper No.107, ICRIER New Delhi.

4. Topalova, Peita (2004), Trade Liberalization and Firm Productivity : The case of India, IMF Working Paper, No. WP/04/28.

5.Goldar, B.N. (1986), Productivity Growth in Indian Industry, Allied Publishers Private Limited, New Delhi.

6.Kendrick, J.W. (1961), Productivity Trends In The United States, NBER.

7. Solow, R.M. (1957), "Technical Change and Aggregate Production Function', The Review of Economics and Statistics, Vol.39.

8.Nelson, R.R. (1965), 'The CES Production Functions and Economic Growth Projections', The Review of Economics and Statistics.

9. Levhari, E. (1966), "The Relationship Between Two Measures of Total Factor Productivity", The Review of Economics and Statistics.

10.Solow, R.M. (1957), Op.Cit.

11. Griliches, Z. (1967), “The Explanation of Productivity Change’, The Review of Economics and Statistics.

12. Diewert, W.E. (1976), “Exact and Superlative Index Numbers’, Journal of Econometrics.

Indus Code	Description of Industry
21	Manufacture of food products
22	Manufacture of beverages, tobacco and related products
23	Manufacture of cotton textiles
24	Manufacture of wool, silk and man-made fiber textiles
25	Manufacture of Jute and other vegetable fiber textiles (except cotton)
26	Manufacture of textile products (including wearing apparel)
27	Manufacture of wood and wood products, furniture and fixtures
28	Manufacture of paper and paper products and printing, publishing and Allied industries
29	Manufacture of leather and products of leather, fur and substitutes of leather
30	Manufacture of basic chemicals and chemical products (except products of Petroleum and coal)
31	Manufacture of rubber, plastic, petroleum and coal products; processing of Nuclear fields
32	Manufacture of Non-metallic mineral products
33	Basic metal and Alloys industries
34	Manufacture of metal products and parts, except machinery and equipment
35-36	Manufacture of machinery and equipment other than transport equipment (Manufacture PF SCOEMTOFOC equipments, photographic/cinematographic equipment and watches and clocks is Classified in division 38)
37	Manufacture of transport equipment and parts
38	Other manufacturing industries
39	Repair of capital goods
40	Electricity
41	Gas and steam generation and distribution through pipes
42	Water works and supply
43	Non-conventional energy generation and distribution
74	Storage and warehousing services
97	Repair services

LIST OF SELECT 16 STATES

1.ANDHRA PRADESH

2.ASSAM

3.BIHAR

4.GUJARAT

5.HARYANA

6.HIMACHAL PRADESH

7.KARNATAKA

8.KERALA

9.MADHYA PRADESH

10. MAHARASHTRA

11. ORISSA

12. PUNJAB

13. RAJASTHAN

14. TAMIL NADU

15. UTTAR PRADESH

16. WEST BENGAL

LIST OF TABLES

TABLE 1

ESTIMATES OF KENDRICK INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
Andhra pradesh	100	110.01	135.31	163.15	174.3	149.74	145.41	132.19	145.8	143.63	107.55
Assam	100	119.08	136.73	186.15	190.95	251.24	188.29	212.62	116.88	233.7	221.79
Bihar	100	152.04	166.77	220.86	174.51	186.57	183.53	233.44	301.59	296.15	298.62
Gujarat	100	107.31	107.46	135.13	126.21	123.97	126.03	123.28	136.64	131.84	119.54
Haryana	100	118.69	122.21	142.02	109.04	109.61	113.68	115.74	122.13	127.27	149.88
Himachal Pradesh	100	102.11	94.59	112.44	83.24	86.78	86.58	61.47	101.57	84.2	112.59
Karnataka	100	108.51	112.53	141.31	129.35	134.4	136.76	127.98	131.73	163.3	176.35
Kerala	100	101.02	102.93	103.96	131.29	114.55	116.88	133.04	132.14	169.73	128.44
Madhya Pradesh	100	107.9	107.63	102.57	95.92	116.6	92.77	115.49	176.61	136.05	147.61
Maharashtra	100	102.13	103.16	112.19	114.78	134.2	123.81	118.77	131.56	130.64	136.29
Orissa	100	93.32	83.99	97.63	74.77	100.01	106.28	76.54	116.27	131.79	141.77
Punjab	100	98.73	92.82	96.33	97.34	108.71	105.43	113.58	109.77	173.54	141.71
Rajasthan	100	101.34	97	134.36	110.78	114.03	135.15	122.03	125.42	152.33	168.98
Tamil Nadu	100	100.11	111.58	109.41	121.06	105.31	108.09	105.55	109.76	125.6	128.3
Uttar Pradesh	100	177.26	159.69	141.95	142.28	151.93	199.26	205.22	216.66	265.5	246.32
West Bengal	100	99.32	103.42	104.79	108.7	107.75	123.17	135.21	105.26	101.17	121.03
Mean	100	112.43	114.86	131.52	124.03	130.96	130.7	133.26	142.49	160.4	159.17

ESTIMATES OF KENDRICK INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02
Andhra pradesh	113.19	125.94	127.02	168.1	217.73	177.74	206.56	179.14	192.1	195.7	201.5
Assam	185.2	172.12	179.7	165.22	159.87	145.83	103.82	215.39	220	84.62	98.16
Bihar	329.38	318.83	485.9	278.29	323.22	390.98	596.05	416.89	566.97	410.63	304
Gujarat	111.25	149.31	139.28	157.05	116.44	134.61	91.71	106.4	119.65	100.59	89.54
Haryana	144.05	123.33	128.59	166	203.3	202.03	171.81	182.11	190.1	163.39	184.35
Himachal Pradesh	106.04	100.47	143.36	115.96	108.12	108.52	128.45	115.92	132.52	143.74	123.96
Karnataka	215.13	191.45	178.38	411.26	178.27	173.33	123.82	94.04	110.94	131.06	117.73
Kerala	154.41	147.75	135.37	150.58	144.02	174.73	122.82	206.83	176.46	165.14	150.05
Madhya Pradesh	139.1	140.66	163	153.64	193.29	169.46	209.79	141.94	183.55	229.42	242.58
Maharashtra	114.59	132.88	141.84	146.95	148.92	117.41	123.36	148.11	137.48	131.68	123.7
Orissa	126.84	119.76	114.75	101.68	108.87	77.4	155	130.21	170.47	133.97	118.94
Punjab	119.64	148.26	136.37	151.09	138.32	159.06	144.69	266.13	260.59	235.79	290.97
Rajasthan	194.4	173.21	221.05	191.07	201.3	163.82	219.22	196.45	175.81	238.4	218.54
Tamil Nadu	122.77	122.48	127.8	114.02	124.15	117.34	111.46	110.08	114.62	128.52	119.17

Uttar Pradesh	261.29	255.36	284.23	284.67	294.49	305.81	289.77	191.33	253.87	264.21	309.36
West Bengal	110.84	96.7	98.98	96.97	106.05	116.69	142.13	218.31	133.87	137.52	111.7
Mean	159.26	157.41	175.35	178.28	172.9	170.92	183.78	182.45	196.19	180.9	175.27

ESTIMATES OF KENDRICK INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	2002-03	2003-04	2004-05	2005-06	**MEAN OF 80S**	**MEAN OF 90S**	**OVERALL MEAN**	**CGR**
Andhra pradesh	208.71	230.8	264.5	253.44	137.011	190.8107	168.0492	2.84
Assam	167.51	184.81	176.72	160.46	177.948	161.2953	168.3408	-0.22
Bihar	280.38	222.15	316.75	183.22	210.371	361.576	297.6046	3.24
Gujarat	119.71	136.36	163.27	153.28	121.583	125.8967	124.0715	0.31
Haryana	214.69	237.99	269.1	272.98	120.934	190.2547	160.9265	3.51
Himachal Pradesh	158.29	120.1	141.31	239.88	93.2336	132.4427	115.8542	2.49
Karnataka	133.55	146.07	190.37	169.61	132.929	171.0007	154.8935	0.83
Kerala	171.93	185.8	176.83	183.98	121.271	163.1133	145.4108	2.35
Madhya Pradesh	209.59	209.33	176.24	200.9	118.105	184.166	156.2169	3.41
Maharashtra	129.76	141.32	150.11	197	118.866	139.0073	130.4862	1.37
Orissa	161.28	139.04	232.28	167.6	102.034	137.206	122.3254	2.6
Punjab	233.63	267.59	252.26	223.15	112.542	201.836	164.0577	4.7
Rajasthan	225.74	238.74	273.96	296.99	123.765	215.2467	176.5431	4.07
Tamil Nadu	105.34	121.89	125.27	133.37	111.343	119.8853	116.2712	0.57
Uttar Pradesh	363.91	381.44	410.06	387.14	182.37	302.4627	251.6542	4.11
West Bengal	128.61	143.49	179.32	154.4	109.984	131.7053	122.5154	1.67
Mean	188.29	194.18	218.65	211.09	130.89	182.99	160.95	2.57

CGR REPRESENTS COMPOUNDED GROWTH RATE

TABLE 2

ESTIMATES OF SOLOW INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
Andhra Pradesh	100	110.48	123.05	132.03	133.74	108.41	102.5	91.68	94.36	91.47	71.06
Assam	100	118.17	131.48	160.47	159.04	198.43	154.91	174.77	83.51	133.91	128.45
Bihar	100	123.65	124.34	146.11	102.66	106.82	102.36	127.67	154.34	141.85	140.27
Gujarat	100	104.17	101.55	115.02	105.21	102.13	102.02	98.8	107.53	103.46	95.5
Haryana	100	129.66	136.55	120.34	118.44	109.24	106.27	119.2	107.79	110.67	109.43
Himachal Pradesh	100	95.07	80.21	93.66	61.08	63.31	62.81	37.74	56.46	44.65	53.79
Karnataka	100	101.03	101.25	115.35	103.13	102.63	102.23	92.13	91.68	108.2	112.16
Kerala	100	98.18	89.66	85.67	92.3	83.89	91.09	96.34	92.24	91.96	82.1
Madhya Pradesh	100	97.5	90.92	79.28	71.16	77.09	56.5	65.44	99.45	67.6	69.01
Maharashtra	100	95.75	93.51	95.15	94.55	105.03	94.67	89.38	94.64	92.02	94.3
Orissa	100	88.7	74.21	78.72	53.73	66.8	65.98	44.51	55.37	61.39	65.94
Punjab	100	97.19	82.11	78.14	79.01	83.03	75.72	79.75	72.82	93.7	69.36
Rajasthan	100	95.53	88.87	113.08	82.62	78.79	86.37	79.57	74.99	92.07	90.33
Tamil Nadu	100	95.09	101.75	95.85	103.14	86.55	87.39	84.43	85.41	95.33	96.2
Uttar Pradesh	100	128.47	105.44	84.27	80.97	83.79	94.54	96.13	97.02	109.46	96.37
West Bengal	100	91.23	90.72	87.54	88.14	81.99	95.99	98.68	71.65	67.96	77.42
MEAN	100	104.37	100.976	105.043	95.5575	96.1206	92.5844	92.2638	89.9538	94.1063	90.7306

ESTIMATES OF SOLOW INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
Andhra Pradesh	74.1	80.99	80.95	102.31	130.1	104.8	118.75	101.98	108.86
Assam	106.99	100.14	104.58	97.71	96.04	84.29	67.9	113.29	116.25
Bihar	142.98	136.6	158.73	50.44	55.23	62.8	84.11	70.35	86.17
Gujarat	88.4	105.82	99.78	110.25	89.03	101.16	65.02	73.49	81.75
Haryana	102.68	109.61	102.36	112.58	116.8	109.88	112.62	112.68	101.49
Himachal Pradesh	49.2	45.79	55.68	42.59	38.69	37.14	43.91	37.82	43.33
Karnataka	133.43	115.98	107.02	109.13	102.29	98.53	67.11	52.95	62.86
Kerala	89.66	87.22	72.97	83.1	72.6	102.63	67.63	78.24	83.61
Madhya Pradesh	64.58	60.66	67.38	60.16	71.84	61.3	75.55	42.69	51.01
Maharashtra	77.7	86.04	90.14	92.68	93.42	73.46	76.81	93.4	88.13
Orissa	58.07	54.24	51.56	45.62	47.79	33.04	53.73	42.78	53.58
Punjab	50.29	59.52	52.54	55.37	47.44	51.7	44.79	77.73	72.25
Rajasthan	105.44	84.76	112.37	87.5	91.32	69.81	83.22	74.72	61.34
Tamil Nadu	91.79	91.2	94.02	85.45	92.31	87.62	82.95	82.23	85.38
Uttar Pradesh	95.65	91.68	98.04	93.98	96.94	97.93	91.07	54.37	72.75

West Bengal	71.27	63.73	65.68	64.7	70.26	76.61	90.96	151.61	101.72
MEAN	87.6394	85.8738	88.3625	80.8481	82.0063	78.2938	76.6331	78.7706	79.405

ESTIMATES OF SOLOW INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	2001-02	2002-03	2003-04	2004-05	2005-06	**MEAN 80S**	**MEAN 90S**	**OVERALL MEAN**	**CGR**
Andhra Pradesh	113.41	117.7	126.49	143.45	162.69	105.34	111.9	109.0144	0.79
Assam	45.56	59.24	64.92	61.96	55.6	140.29	83.891	108.7044	-4.15
Bihar	32.72	26.99	19.81	27.08	6.47	124.55	68.606	93.222	-7.62
Gujarat	64.12	80.94	90.75	81.46	93.76	103.22	87.552	94.4448	-1.39
Haryana	106.99	116.88	127.32	125.67	121.08	115.24	112.76	113.8492	-0.02
Himachal Pradesh	38.39	47.86	34.92	41.89	57.19	68.071	43.886	54.5272	-2.9
Karnataka	66.89	74.34	80.49	99.38	87.06	102.71	89.819	95.49	-1.57
Kerala	81.99	85.36	91.98	89.79	136.47	91.221	87.375	89.0672	-0.06
Madhya Pradesh	63.95	65.06	54.6	54.89	44.1	79.45	59.841	68.4688	-2.28
Maharashtra	78.94	82.3	88.3	93.07	114.52	95.364	87.779	91.1164	-0.37
Orissa	36.3	47.29	41.45	61.13	64.38	68.668	49.354	57.8524	-2.22
Punjab	83.79	59.28	71.96	67.73	68.52	82.803	61.636	70.9496	-1.3
Rajasthan	82.55	87.84	91.8	105	114.46	89.293	89.438	89.374	-0.09
Tamil Nadu	84.19	75.1	85.05	87.35	133.01	93.74	89.832	91.5516	-0.25
Uttar Pradesh	88.92	85.46	173.65	185.01	172.89	97.86	107.02	102.992	0.75
West Bengal	91.43	103.45	114.2	136.88	117.49	86.484	94.285	90.8524	1.15
MEAN	72.50875	75.94313	84.85563	91.35875	96.85563	96.51	82.81	96.86	-0.69

CGR REPRESENTS COMPOUNDED GROWTH RATE

TABLE 3

ESTIMATES OF DIVISIA INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
Andhra Pradesh	100	95.73	101.24	104.02	104.65	106.79	103.67	102.16	104.56	97.45	95.72
Assam	100	99.44	92.11	100.62	106.42	113.53	109.14	103.14	97.47	104.72	99.26
Bihar	100	97.64	88.77	97.77	103.44	111.15	106.89	103.53	102.95	110.01	102.05
Gujarat	100	101.83	100.19	97.502	97.8939	96.743	94.915	92.061	95.151	94.839	94.59
Haryana	100	104.53	104.56	99.222	95.3022	96.192	95.41	96.688	96.947	99.508	101.22
Himachal Pradesh	100	101.43	108.03	107.33	109.54	109.8	105.82	105.29	105.53	102.04	106.1
Karnataka	100	103.45	101.1	101.24	97.5226	97.162	95.627	97.158	98.076	101.08	103.28
Kerala	100	100.64	95.812	88.344	87.6651	88.831	89.1	91.734	92.932	95.496	90.958
Madhya Pradesh	100	98.44	98.611	90.841	97.5974	87.45	89.332	95.698	114.39	109.21	106.49
Maharashtra	100	100.73	100.96	99.067	98.2063	101.24	98.91	96.386	96.995	99.047	100.86
Orissa	100	110.56	101.97	100.92	101.548	102.35	104.21	101.27	114.96	111.8	109.8
Punjab	100	101.79	100.69	97.201	95.6133	98.705	96.54	100.84	99.804	109.04	104.53
Rajasthan	100	100.83	96.356	98.261	96.5212	100.83	101.03	96.72	100.37	104.37	106.31
Tamil Nadu	100	100.24	100.87	95.03	96.37	94.63	93.96	93.97	93.06	96.7	95.71
Uttar Pradesh	100	108.99	112.4	104.22	106.8	103.1	105.93	107.74	110.05	115.36	115.08
West Bengal	100	100.39	97.76	95.6	94.55	97.39	97.11	97.06	94.17	95.53	96.13
Mean	100	101.67	100.09	98.575	99.3525	100.37	99.225	98.84	101.09	102.89	101.76

ESTIMATES OF DIVISIA INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

STATES	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
Andhra Pradesh	97.42	98.35	100	100.69	100.83	98.48	97.68	97.89	98.47
Assam	96.91	93.2	90.13	88.56	89.55	88.22	87.66	92.8	85.22
Bihar	101.98	100.05	91.36	90.93	95.81	91.73	95.19	94.05	87.18
Gujarat	93.3182	96.292	93.466	94.557	94.494	92.858	95.83	95.026	92.07515
Haryana	97.3857	98.034	97.136	102.21	105.87	103.42	100.61	96.284	101.9647
Himachal Pradesh	106.331	102.92	106.61	108.46	111.07	113.82	112.53	114.06	113.2981
Karnataka	105.771	103.94	99.761	103.13	103.58	100.77	96.967	96.604	92.72809
Kerala	96.667	97.146	89.83	86.948	98.208	100.48	97.459	100.37	103.3194
Madhya Pradesh	110.874	109.6	113.09	102.34	121.84	115.96	129.78	79.201	90.38844
Maharashtra	95.1679	95.529	94.288	95.678	93.571	86.947	89.436	89.426	93.02122
Orissa	112.73	110.15	106.43	104.09	107.54	105.21	111.1	104.26	107.3965
Punjab	103.642	106.11	104.85	106.14	107.12	104.01	105.18	108.97	112.1702
Rajasthan	108.316	106.71	111.14	109.43	111.48	106.81	110.96	105.11	104.9756

Tamil Nadu	95.95	95.48	96.22	97.84	99.46	96.41	97.91	92.59	97.45
Uttar Pradesh	110.32	110.77	111.99	111.67	113.21	107.85	108.94	91.45	93.19
West Bengal	93.74	92.6	92.13	91.85	91.48	92.55	93.26	91.16	90.1
Mean	101.658	101.05	99.902	99.657	102.82	100.35	101.91	96.828	97.68421

ESTIMATES OF DIVISIA INDEX OF TOTAL FACTOR PRODUCTIVITY GROWTH FOR THE 16 STATES OF INDIAN INDUSTRIAL SECTOR: 1980-81 TO 2005-06

							Mean	**Mean of**	**overall**	
STATES	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	**80S**	**90S**	**mean**	**CGR**
Andhra Pradesh	95.82	92.19	93.93	93.48	95.01	100.88	101.45	97.408	99.1196	-0.29
Assam	82.29	75.8	84.58	88.46	93.77	99.86	102.35	89.134	94.7254	-0.8
Bihar	85.45	76.08	81.84	87.77	95.53	84.21	102.2	90.61067	95.5138	-0.82
Gujarat	92.513	93.69	97.772	97.2311	98.543	105.664	96.884	95.5556	96.1175	-0.05
Haryana	96.77	93.47	95.678	96.8456	98.777	104.138	99.053	99.23922	99.1606	-0.04
Himachal Pradesh	115.5	105.3	99.255	106.171	98.242	126.78	105.54	109.3583	107.742	0.24
Karnataka	92.45	92.21	93.864	95.3559	99.261	107.305	99.609	98.91407	99.2081	-0.14
Kerala	101.35	91.79	93.608	96.6508	97.337	104.971	92.865	97.07613	95.2944	0.28
Madhya Pradesh	91.542	83.8	82.928	90.7099	82.842	84.762	98.914	99.31054	99.1429	-0.45
Maharashtra	92.33	87.83	89.386	90.2068	98.684	99.4053	99.309	92.72699	95.5115	-0.4
Orissa	107.84	108.5	107.46	107.482	105.19	113.562	105.4	107.9324	106.86	0.2
Punjab	102.25	101.8	98.358	98.9093	98.564	103.436	100.43	104.0979	102.547	0.15
Rajasthan	105.54	100.8	98.036	98.4538	98.917	107.037	100.15	105.5839	103.283	0.2
Tamil Nadu	99.78	93.14	92.01	95.44	98.94	106.45	96.413	97.00467	96.7542	0.02
Uttar Pradesh	92.36	91.22	94.7	95.99	97.26	100.87	108.15	102.1193	104.672	-0.54
West Bengal	91.39	91.07	91.23	91.09	99.35	104.38	96.881	93.15867	94.7335	-0.19
Mean	96.574	92.42	93.415	95.6404	97.264	103.357	100.35	98.7	99.11	-0.15

CGR REPRESENTS COMPOUNDED GROWTH RATE