A Decomposition of Total Factor Productivity Growth : A Regional Analysis of Indian Industrial Manufacturing Growth

Surender Kumar

A Decomposition of Total Factor Productivity Growth : A Regional Analysis of Indian Industrial Manufacturing Growth

*Surender Kumar**

Abstract

Total factor productivity (TFP) growth in industrial manufacturing is measured for 15 major Indian states for the period 1982-83 to 2000-01 using non-parametric linear programming methods. TFP growth is decomposed into efficiency and technological changes and also measure for the bias in technical change. The resulting information is used to examine whether the post-reform period shows any improvement in productivity and efficiency in comparison to the pre-reform one. Findings of the present exercise indicate the improvement in TFP. The recent change in TFP is governed by the technical progress in contrast to similar gain caused by the improvement in technical efficiency in the pre-reform regime. The technological progress in state manufacturing exhibited a capital using bias during the study period. Regional differences in TFP persist, although the magnitude of variation has declined in the post-reform period. Moreover, it is also found that there is

---

Fellow, National Institute of Public Finance and Policy, 18/2 Satsang Vihar Marg, Special Institutional Area, Near JNU, New Delhi 110067 India. E-mail: surender@nipfp.org.in surenderkumarbansal@hotmail.com

Acknowledgements: The author wishes to thank Professors B. N. Goldar and Gopinath Pradhan for encouragement and for their comments and suggestions on the earlier version of this paper. However, the disclaimer applies.

a tendency of convergence in terms of TFP growth rate among Indian states during the post-reform years and only the states that were technically efficient at the beginning of the reform remain innovative.

A Decomposition of Total Factor Productivity Growth : A Regional Analysis of Indian Industrial Manufacturing Growth

Introduction

Since 1980, India's rate of GDP growth has more than doubled, rising from 1.7 percent in 1950-80 to 3.8 percent in 1980-2000. Such a development is ascribed to liberalisation of the economy by many experts working in the area. It is pointed out that until 1991, India had been one of the most over-regulated and closed economies in the world. Up to this point the Central Government's control over industrial development was maintained through public ownership and license-permit-quota system. Planned industrialisation took place in a highly protected environment, which was maintained by high tariff, non-tariff barriers and controls on foreign investment, together forming a set of policy tools that impeded rather than facilitating the growth process of the economy. *The New Industrial Policy* introduced in 1991 is considered a watershed event for the Indian economy that shattered this old order. Trade liberalisation and deregulation became the central elements. Here it should be noted that the pickup in India's industrial growth precedes the 1991 liberalisation by a full decade. Even a cursory glance at the industrial growth record shows that India's rate more than doubled during 1980s, with very little discernible change in trend after 1991. During the first half of 1980s the government's attitude towards business went from being outright hostile to supportive, which was further reinforced, in a more explicit manner, in the second half of 1980s. Rodrik and Subramanian (2004) have characterised the policy changes of 1980s and 1991 as pro-business and pro-market reforms, respectively. The former focuses on raising the profitability of the established industrial and commercial establishments. It tends to favour the incumbents by erasing restrictions on capacity expansion, removing price controls, and reducing corporate taxes. A pro-market orientation, in contrast, removes the bottlenecks to markets and aims to achieve this through economic liberalisation by favouring new entrants and consumers.

Looking into the underlying forces responsible for the changed growth process, the recent works by Burgess and Venables (2003) and Foster and Rosenzweig (2003) show that it is non-agricultural productivity that appears to be the driver of aggregate outcomes at state levels. A number of studies also have argued that manufacturing experienced a surge in productivity in 1980s (Ahluwalia, 1995; Unel, 2003; RBI, 2004). For example, Unel shows that under the assumption of perfect competition, the average annual growth rate of total factor productivity (TFP) is 1.8 percent and under the assumption of a constant labour elasticity of 0.6, it is 3.1 percent over the period of 1979-80 to 1997–98. However, there is another set of studies, which contains evidence on the declining TFP growth in the post-reform years (*see* for example, Das, 2003; Goldar, 2004). The role of TFP, estimated from manufacturing sector in the spurt of growth of the Indian economy, therefore, remains an unresolved problem.

Studies on TFP estimation by far are based on average production function and growth accounting methodology. They assume that a firm is operating on its production frontier. Moreover, TFP is treated analogous to technical change. Such an interpretation is prone to serious limitations as several restrictive assumptions, such as constant returns to scale and allocative and technical efficiency have to be made.

In contrast to the approach adopted by growth accounting and econometric studies, Ray (2002) uses non-parametric linear programming techniques to construct the Malmquist productivity index. In measuring the annual rates of change in productivity and technical efficiency in manufacturing for individual states in India, he uses the data for the period 1986-87 to 1995-96. Results of this study show that, on average, the annual rate of productivity growth has been higher in the 1990s in comparison to the 1980s. It has also been pointed out that some states have actually experienced a slowdown or even productivity decline in the 1990s. However, Ray's decomposition of Malmquist productivity index contains no index reflecting the contribution of productivity change of biased technical change.

The present paper extends the work of Ray (2002) not only by including more number of years but also by further decomposition of the technical progress into pure technical progress, input-biased as well as output-biased technical progress. In the process it succeeds in determining whether during the reform period technical progress was either labour or capital deepening.

In the last two decades, the productivity growth measurement literature has been extended from the standard calculations of TFP employing production function framework towards more refined decomposition methods. To overcome the shortcomings of growth accounting approach and to identify the components of productivity change, techniques have been developed that are based on the decomposition of TFP index. A method of measuring productivity with growing popularity is the use of Malmquist index. After its use from a non-parametric perspective by Caves, Christensen and Diewert (1982), who developed it as a way of measuring output produced per unit of input, Fare, *et.al*. (1994) went further and employed Shepherd output distance functions and a non-parametric linear programming approach to measure productivity change for OECD countries.

The Malmquist index has several features, which make it an attractive approach. First, it is a TFP index (Fare and Primont, 1995). Second, it can be constructed using distance functions, which are primal measures based only on input and output quantities rather than price. Third, the index can be decomposed into technical efficiency change, technical change and scale effect components. Efficiency change can be further decomposed into pure efficiency change and scale components. The technical change component can also be decomposed into pure technical change, input-biased as well as output-biased technical change components. As efficiency and technical changes are analogous to the notions of technological innovation and adoption respectively, the dynamics of the recent growth observed in the manufacturing sector of the Indian economy can be appreciated better. Finally, assumptions do not need to be made with regards to objectives of firms or regions in terms of, say, cost minimisation or profit maximisation objectives, which could be inappropriate in certain situations.

The remainder of the paper is structured as follows: Section II outlines the methodological issues related to the measurement of TFP. Empirical results derived from these models and discussions are presented in Section III. The present analysis, therefore, allows us to present the efficiency and productivity scores and factors explaining the productivity. The final section summarises the findings of the study.

II. Methodology

We use linear programming techniques to construct the Malmquist productivity index for the major states of India. Our analysis is confined to the measurement of TFP growth in manufacturing sector, which is decomposed into efficiency and technological changes with an isoquant serving as reference technology. Such a method also allows determination of the nature of technological change, either capital or labour deepening, in the Hicksian sense.

As noted above, to measure TFP in state manufacturing, we use non-parametric linear programming (LP). The LP approach has two advantages over the econometric one in measuring productivity change (Grosskopf, 1986). First, it compares the states to the 'best' practice technology rather than 'average' practice technology as is done by econometric studies. Second, it does not require the specification of an *ad hoc* functional form or error structure. In the process, the LP approach allows recovery of various efficiency and productivity measures in an easily calculable manner. Specifically, it is able to answer questions related to technical efficiency, scale efficiency, and productivity change.

We employ input distance function to construct the various measures of efficiency and productivity, which allows estimation of a multiple output, multiple input production technology. It gives the maximum proportional contraction of all inputs that still allows a state to produce a given level of manufacturing output. It is the reciprocal of input-based Farrell measure of technical efficiency and provides the theoretical basis for the Malmquist productivity index.

Let $\mathbf{x}^t = (x_1^t, x_2^t, ..., x_N^t)$ denote an input vector at period t with i=1,2,…,N inputs and $\mathbf{y}^t = (y_1^t, y_2^t, ...y_M^t)$ an output vector at period t with j=1,2,…,M where $\mathbf{x}^t \in \Re_+^N$ and $\mathbf{y}^t \in \Re_+^M$. The technology can be represented by the input requirement set as follows:

$$L^t(\mathbf{y}^t) = \{\mathbf{x}^t : (\mathbf{x}^t, \mathbf{y}^t) \in S^t\}, t = 1, ..., T \qquad (1)$$

where $S^t = \{(\mathbf{x}^t, \mathbf{y}^t) : \mathbf{x}^t \text{ can produce } \mathbf{y}^t\}$ is the technology set at period t. The input requirement set provides all the feasible input vectors that can produce the output vector. The input distance function requires information on input and output quantity and is independent of input prices as well as behavioural assumptions on producers. Figure 1 illustrates the input distance function for a two input case. The frontier technology is given by piecewise linear isoquant, $L^t(\mathbf{y}^t)$. Efficient production activities occur at the extreme points of the convex hull of the frontier (B and C). The vertical and horizontal segments of the frontier lines indicate the strong (free) disposability of inputs. Production activities inside the input requirement set indicate the presence of inefficiency in those activities. For example, production activity c is inside the input requirement set and therefore inefficient. Ob/Oc gives the technical efficiency of production activity c in terms of input distance function at period t. When the observation falls on the efficient range, the value of input distance function is equal to one.

Let there be k=1,2,…..,K^t firms that produce M outputs $y_m^{k,t}, m = 1, ..., M$ using N inputs $x_n^{k,t}, n = 1, ..., N$, at each time period t=1,….,T. A piecewise linear requirement set at period t is defined as:

$$L^t(y^t) = \{x^t : \sum_{k=1}^{K} z_k^t y_{km}^t \geq y_m^t \qquad m=1,........,M$$

$$\sum_{k=1}^{K} z_k^t x_{kn}^t \leq x_n^t \qquad n=1,........,N \qquad (2)$$

$$z_k^t \geq 0 \qquad k=1,.........,K\}$$

where z_k^t indicates intensity level, which makes the activity of each observation expand or contract to construct a piecewise linear technology (Fare, Grosskof, and Lovell, 1994). The constraint z_k^t >0 implies constant returns to scale (CRS). By controlling the intensity variable with additional constraints, i.e., $\sum_{k=1}^{K} z_k^t = 1$ and $\sum_{k=1}^{K} z_k^t \leq 1$ in the linear programme, variable returns to scale (VRS) and non-increasing returns (NRS) to scale can be imposed (Afriat, 1972).

Let us define $D_i^t(\mathbf{x}^t, \mathbf{y}^t)$ as Shephard's input distance function at period t with strong disposability of inputs assumption as:

$$D_i^t(\mathbf{x}^t, \mathbf{y}^t) = \max\{\lambda : (\mathbf{x}^t / \lambda) \in L^t(\mathbf{y}^t)\} \qquad (3)$$

Where $D_i^t(\mathbf{x}^t, \mathbf{y}^t)$ estimates the maximum possible contraction of $\mathbf{x}^t$ and can be termed as a measure of overall technical efficiency (OTE). OTE can be further decomposed into a product of pure technical efficiency (PTE) and input scale efficiency (ISE). That is, $OTE = PTE \times ISE.$ Pure technical inefficiency is due to overemployment of inputs, while scale inefficiency is due to the states not operating in the range of CRS. The value of input distance function under VRS provides the measure of PTE. Input scale efficiency is then equal to $ISE = OTE / PTE$ (Fare et al., 1994).

The Malmquist productivity index (MALM) yields a convenient way of decomposing TFP change into technical change (TECH) and overall technical efficiency change (OTEC). In order to estimate the

Malmquist productivity index from period t to t+1, additional distance functions required are:

$$D_i^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) = \max\{\lambda : (\mathbf{x}^{t+1}/\lambda) \in L^t(\mathbf{y}^{t+1})\} \tag{4}$$

$$D_i^{t+1}(\mathbf{x}^t, \mathbf{y}^t) = \max\{\lambda : (\mathbf{x}^t/\lambda) \in L^{t+1}(\mathbf{y}^t)\} \tag{5}$$

and

$$D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) = \max\{\lambda : (\mathbf{x}^{t+1}/\lambda) \in L^{t+1}(\mathbf{y}^{t+1})\} \tag{6}$$

The cross period distance function, $D_i^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})$, indicates the efficiency measure using the observation at period t+1 relative to the frontier technology at period t, and $D_i^{t+1}(\mathbf{x}^t, \mathbf{y}^t)$ shows the efficiency measure employing the observation at period t relative to the frontier technology at period t+1. In Figure 1, the input requirement set for period t+1 is given by $L^{t+1}(y^{t+1})$, and $D_i^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})$ and $D_i^{t+1}(\mathbf{x}^t, \mathbf{y}^t)$ are given by Oe/Of and Oc/Oa respectively. Cross period distance functions take values of less than, equal to, or more than one. Similarly, $D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})$ is given by Oe/Od.

The MALM consists of four input distance functions to avoid choosing arbitrary base period and the geometric mean of two input based technical efficiency indices is taken to form:

$$MALM = \left[\frac{D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_i^{t+1}(\mathbf{x}^t, \mathbf{y}^t)} \times \frac{D_i^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_i^t(\mathbf{x}^t, \mathbf{y}^t)}\right]^{0.5} \tag{7}$$

The MALM can be decomposed into OTEC and TECH as:

$$MALM = \underbrace{\frac{D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_i^t(\mathbf{x}^t, \mathbf{y}^t)}}_{OTEC} \underbrace{\left[\frac{D_i^t(\mathbf{x}^t, \mathbf{y}^t)}{D_i^{t+1}(\mathbf{x}^t, \mathbf{y}^t)} \times \frac{D_i^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}\right]^{0.5}}_{TECH} \tag{8}$$

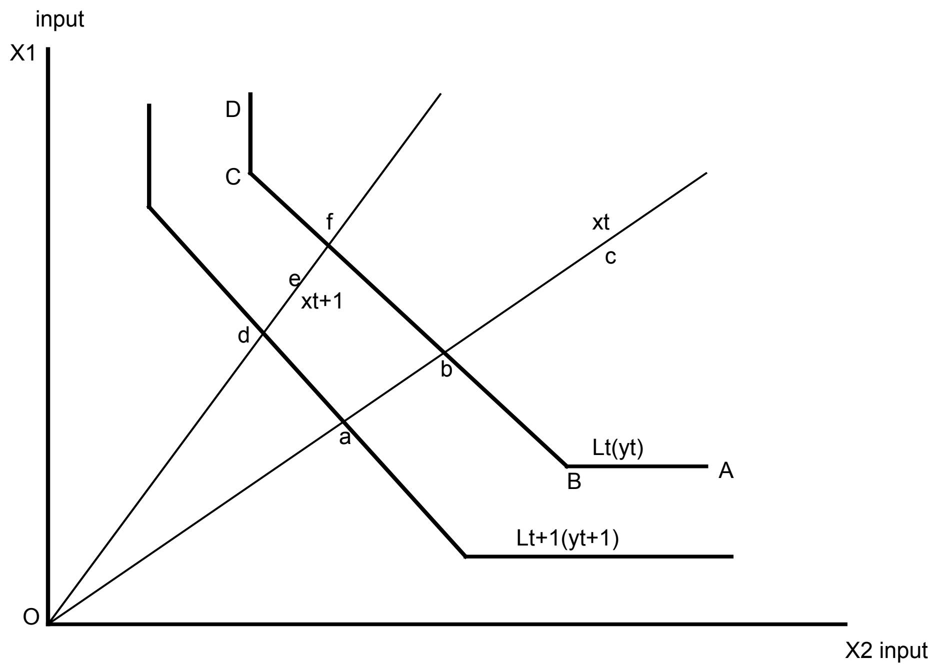

Figure 1. Input-Oriented Distance Function and the Malmquist Productivity Index

Where the first term defines the changes in OTE from period t to t+1, i.e., moving closer to the isoquant or 'catching up'. The second term, i.e., the geometric mean (GM) in parenthesis, represents changes in technology, i.e., a shift in the frontier from period t to period t+1. Recall that $OTE = PTE \times ISE$. Therefore, OTEC can be further decomposed into pure technical efficiency change, PTEC, and input scale efficiency change, ISEC, where $PTEC = PTE^{t+1} / PTE^{t}$ and $ISEC = ISE^{t+1} / ISE^{t}$. The MALM can be written as:

$$MALM = PTEC \times ISEC \times TECH \tag{9}$$

In the input-oriented case all the indices can be interpreted as progress, no change, and regress, when their values are less than one, equal to one, and greater than one respectively. Following Fare, Grifell-Tatje, Grosskopf, and Lovell (1997), the TECH can be decomposed into a product of output-biased technological change (OBTECH), input-biased technological change (IBTECH) and the magnitude of technological change (MATECH). Thus,

$$TECH = OBTECH \times IBTECH \times MATECH \tag{10}$$

where

$$OBTECH = \left[\frac{D_i^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})}{D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})} \times \frac{D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t})}{D_i^{t}(\mathbf{x}^{t+1}, \mathbf{y}^{t})} \right]^{0.5}$$

$$IBTECH = \left[\frac{D_i^{t+1}(\mathbf{x}^{t}, \mathbf{y}^{t})}{D_i^{t}(\mathbf{x}^{t}, \mathbf{y}^{t})} \times \frac{D_i^{t}(\mathbf{x}^{t+1}, \mathbf{y}^{t})}{D_i^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t})} \right]^{0.5}$$

and

$$MATECH = \frac{D_i^t(\mathbf{x}^{t}, \mathbf{y}^{t})}{D_i^{t+1}(\mathbf{x}^{t}, \mathbf{y}^{t})}$$

Since, we are considering only one output in the present study, there will be no output-biased technological change, i.e., OBTECH=1, and equation (10) reduces to

$$TECH = IBTECH \times MATECH \qquad (11)$$

IBTECH measures the shift in the isoquant from period t to t+1 due to changes in technology holding the level of output constant at $\mathbf{y}^t$. The definition of Hicks' neutral, capital- or labour-deepening technological change depends on, under constant capital-labour ratio, the marginal rate of substitution of labour for capital (MRS_{LK}) remaining constant, decreasing, or increasing (*see* Binswanger, 1974). Following Fare, Grosskopf, and Lee (1995) and Weber and Domazlicky (1999) IBTECH is independent of outputs under CRS when states produce a single output. Figure 2 describes how the value of IBTECH and change in the capital-labour (K/L) ratio can be used to identify the capital- or labour-deepening character of technological change. Assume y=1, x_1=labour (L) and x_2=capital (K). Let $L^t(1)$ represent the period t isoquant and $L_n^{t+1}(1)$, $L_1^{t+1}(1)$, and $L_2^{t+1}(1)$ Hicks' neutral, Hicks' labour-deepening (or capital-saving), and capital-deepening (or labour-saving) from period t to t+1. A state is observed to use the input vector $\mathbf{x}^t = (L^t, K^t)$ in period t and $\mathbf{x}^{t+1} = (L^{t+1}, K^{t+1})$ in period t+1 so that $(K/L)^{t+1} < (K/L)^t$. If IBTECH= 1, then $D_i^{t+1}(\mathbf{x}^t,1)/D_i^t(\mathbf{x}^t,1) = D_i^{t+1}(\mathbf{x}^{t+1},1)/D_i^t(\mathbf{x}^{t+1},1)$. In this case Oa=Of/Od, indicating Hicks' neutrality, since MRS_{LK} does not change. If the technology shifts instead to $L_1^{t+1}(1)$, then (Ob/Oa)<(Of/Oc) and IBTECH<1. In this case, IBTECH<1 coupled with the increase in the K/L ratio, indicates a capital-deepening (or labour-saving) technological bias and decrease in the K/L ratio indicates a labour-deepening technological bias. Finally, if the technology shifts to $L_2^{t+1}(1)$, then (Ob/Oa)>(Of/Oe) and IBTECH>1. Therefore, IBTECH>1 coupled with the increase in the K/L ratio indicates a labour-deepening (or capital-saving) technological bias. In other words, when the K/L ratio increases from period t to period t+1, IBTECH<1 indicates a capital-deepening technological bias and IBTECH>1 indicates a labour-deepening technological bias. Table 1 summarises the various kinds of input biased technological changes that may occur.

Table 1: Input Biased Technical Change Direction

	IBTECH>1	IBTECH= 1	IBTECH<1
$(K/L)^{t+1} > (K/L)^{t}$	Labour-deepening	Neutral	Capital-deepening
$(K/L)^{t+1} < (K/L)^{t}$	Capital-deepening	Neutral	Labour-deepening

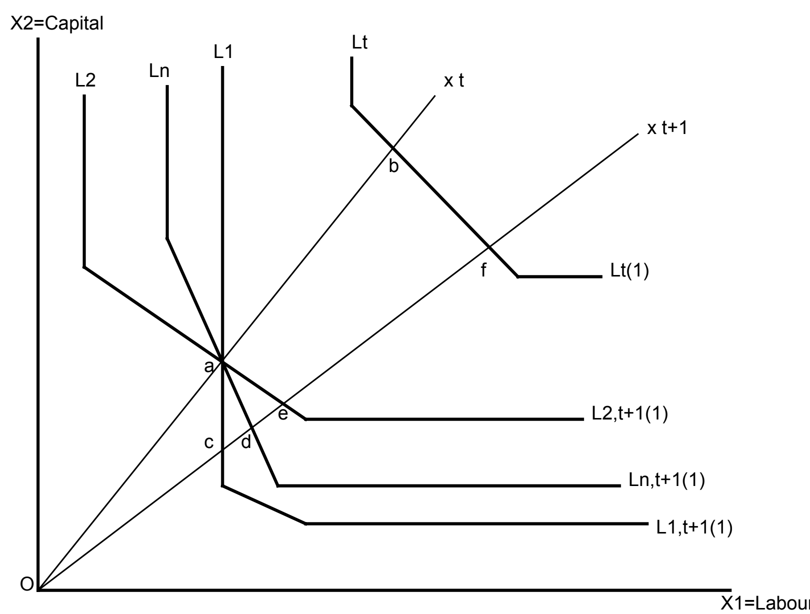

Figure 2. Input Biased Technological Change

III. Data and Discussion of Results

We calculate productivity and its components for fifteen major Indian states[1] over the period of 1982-83 to 2000-01. The period up to 1990-91 is considered as pre-reform while the subsequent period is regarded as post-reform. The data used in this study for calculating productivity and its various components come from the Annual Survey of Industries (ASI) for the relevant years. The manufacturing sector is modelled as an industry producing a scalar output measured by the gross value added at constant prices by employing the factor inputs, labour and capital. Using gross value added at constant prices is a common practice in the Indian empirical literature (e.g., Unel, 2003; Ahluwalia, 1991; Balakrishnan and Pushpangadan, 1994; and Goldar, 1986). One advantage of using the gross value added rather than gross output is that it allows comparison between the firms that are using heterogeneous raw materials (Griliches and Ringstad, 1971). The use of gross output in place of gross value added necessitates the use of raw materials, which may obscure the role of labour and capital in the productivity growth (Hossain and Karunaratne, 2004). Another advantage is that use of gross value added accounts for differences and changes in the quality of inputs (Salim and Kalirajan, 1999).

The input-output data covered by the ASI for individual states are the aggregates of all establishments in the state. The number of establishments covered by the Census varies widely across the states. Therefore, following Ray (1997 & 2002), state level input-output quantity data for the 'representative establishment' are constructed by dividing the state-level aggregate values of the variables by the number of establishments covered in the state. The advantage of using the state level average data is that it imposes fewer restrictions on the production technology.[2] Moreover, such kind of averaging reduces the effects of random noise due to measurement errors in inputs and outputs.

Except for the labour input, which is measured by the total number of persons engaged in an average establishment, ASI reports fixed capital stock and gross value added data in value terms. Nominal values of gross value added were deflated by the wholesale price index for manufactured goods. Fixed capital stock was deflated by the price index for *new* machinery and transport equipment. Both of these variables are measured at 1981-82 prices at all-India level.[3] Measuring the capital stock input is rather problematic. In many studies capital stock is measured by the book value of fixed assets while in others its flow is measured by summing rent, repairs, and depreciation expenses or perpetual inventory created from annual investment data. Needless to point out that each of these measures has its own shortcomings. For example, the book value and perpetual inventory methods do not address the question of capacity utilisation, whereas the flow measure may be questioned on the ground that the depreciation charges in the financial accounts may be unrelated to actual depreciation of hardware. Thus following Ray (2002) in the present study, capital stock is measured by the book value of fixed assets. But to the extent that the true capital input is distorted, it is distorted uniformly in all the states. Therefore, the relative performance of states should not be affected seriously by this shortcoming.

Contemporaneous CRS, VRS, and NRS technology sets were constructed from the state level input-output data for each year. Own period input distance functions were computed for each year under the CRS, VRS, and NRS assumptions. Similarly, cross period input distance functions were also computed for every pair of adjacent years. Yearly MALM and its components were computed for all the states in adjacent years.

Technical Efficiency Estimates

Since the basic components of Malmquist index is related to measures of technical efficiency, we first report these results. Values of unity imply that the state is on the isoquant in the associated year while those exceeding unity imply that it is above the isoquant or technically inefficient. Table 2 provides the geometric means of the components of OTE for the 15 states. On average, inputs employed in state manufacturing could have been contracted by 26.6 percent=($1-1/1.362)\times100$, 28 percent and 25 percent in the overall, pre-reform and post reform[4] periods respectively. The average output loss due to pure technical inefficiency was 13 percent, 16 percent and 11 percent, and the output loss due to scale inefficiency was 33 percent, 35 percent and 32.5 percent respectively for all the three periods. It implies that the pro-market reform has helped in increasing the technical efficiency of Indian states.

The state-wise results of technical efficiency are presented in Table 3. Maharashtra, which is known to be industrially developed, is the most efficient among the states under consideration. It was on the isoquant during the pre-reform era and experienced only 1.2 percent overall technical inefficiency during the post-reform era and all the inefficiencies were due to input scale inefficiency. The table also reveals that the most inefficient states in terms of overall technical efficiency were Punjab in the pre-reform period, West Bengal in the post-reform period, and Andhra Pradesh over the entire period of study. Except for six states (Assam, Kerala, Madhya Pradesh, Maharashtra, Tamilnadu and West Bengal), all others experienced gains in OTE in the post-reform period in comparison to the pre-reform years. Here it should be noted that the inefficiency in majority of the states is due to scale.

Table 4 reports the states operating in the range of CRS, decreasing returns to scale (DRS) and increasing returns to scale (IRS) year-wise. To determine the scale of returns a state operates in, following Grosskopf (1986), we estimate technical efficiency under CRS (T^{CRS}), VRS (T^{VRS}) and NRS (T^{NRS}).[5] In our study most of the states were operating in the range of IRS. Maharashtra operates in the range of CRS in 15 out of 19 years, while Assam operates in the same range in the pre- and post-reform years. Thus the operation of most of the states in the range of IRS helps to explain the cause of inefficiency observed.

Total Factor Productivity Estimates

Next we calculate the Malmquist productivity index along with its components for each state. Instead of presenting the year-wise disaggregated results, we turn to a summary description of the average performance of all states.[6] Recall that if the value of Malmquist index or any of its components is greater than unity, then it denotes regression or deterioration in performance between any two adjacent years. Also it may be necessary to note that these measures capture the performance relative to the best practice one.

Table 5 reports the annual average values of Malmquist index along with those obtained from its decomposition. It can be seen from the table that the Malmquist index does not show a steady upward trend. On the contrary, it indicates productivity decline in 1983-84, 1987-88, 1989-90, 1991-92, and again in 2000-01. In the midst of such variations, however, the average annual rate of productivity growth is higher during the post-reform period than in its preceding regime. The TFP has increased by 1.7 percent and 3.0 percent per annum during pre- and post-reform years respectively. On average, the improvement can be ascribed to technical progress (TECH) (0.4 percent and 2.8 percent respectively) and efficiency improvement (OTECH) (1.2 percent and 0.2 percent respectively). Further decomposition of technical progress indicates that during these two periods the magnitude of pure technical progress (MATECH) was -0.2 percent and 1.6 percent whereas that of IBTECH was 0.6 percent and 1.2 percent. A decomposition of efficiency improvement reveals that in the pre-reform years, the efficiency improvement was governed by the gain in pure technical efficiency (PTEC) (1.7 percent), while in the subsequent period, the improvement in scale efficiency (ISEC) and pure technical efficiency change equally influenced the gain in the overall efficiency change. In nutshell, it can be said that in the pre-reform period, three-fourth of improvement in the total factor productivity was governed by the technical efficiency improvement, whereas in the post-reform years it was the technical progress that governed the growth in total factor productivity.

Results of the present study confirm those of Ray (2002). Ray found that TFP increased from 0.17 percent per year during the pre-reform era (upto 1990-91) to 1.45 percent per year during the post-reform years. Although the rates of growth in TFP obtained by Ray (2002) are different from the ones in the present study, direction of change in both is found to be same, that is, positive growth in the decades of 1980s and 1990s. Another feature common to both the studies is higher growth rate of TFP in the post-reform period compared to its preceding period. The difference in magnitude of estimated growth rates in TFP might be due to difference in orientation of the methodology. While Ray used the output orientation in the measurement of Malmquist index, the present study employed input distance functions for that purpose.

The performance of TFP in each state is given in Table 6 as average annual rates of growth over the period 1982-83 to 2000-01. The table also contains the TFP growth rates for the pre- and post-reform periods. As it is difficult to summarise the disaggregated results, we include some of their general features. The disaggregated results reveal widespread regional variation in productivity changes. In the study period, 9 out of 15 states experienced productivity improvement. While in the pre-reform period 11 states witnessed growth in TFP, the corresponding number was 10 in the post-reform years. In the pre-reform period four states (Orissa, 9.8 percent; Rajasthan, 7.8 percent and Uttar Pradesh, 7.1 percent) witnessed the growth in TFP more than 5 percent per year, whereas in the post-reform years six states (Gujarat, 10.3 percent; Rajasthan, 9.8 percent; Madhya Pradesh, 9.7 percent; Orissa, 6.5 percent; Uttar Pradesh, 5.9 percent and Maharashtra, 5.04 percent) registered more than 5 percent annual change in TFP. The table reveals that the variation in TFP has decreased in the post-reform period in comparison to its preceding years. The coefficient of variation in its growth rate among the states was 301.7 percent and 187.5 percent during the pre- and post-reform periods.

The most significant factor behind the improvement in TFP during period of study could be found in technical progress as evident from the positive rates of technical change in eight states. Here it should be noted (*see,* Table 6) that in the pre-reform era, nine states exhibit technical regress, whereas in the post-reform period only the states of Andhra Pradesh (-1.4 percent), Assam (-4.8 percent), Karnataka (-1.9 percent), Kerala (-4.4 percent), Punjab (-0.09 percent), Tamilnadu (-1.35 percent) and West Bengal (-1.7 percent) exhibited technological regression. Also during the decade of 1980s the contribution of OTE improvement was substantial. But in the 1990s, it was technical progress that contributed significantly to the TFP progress. During both the decades, the progress in TFP in Punjab was only due to the presence of 'catch-up' effect while it was due to innovation in Maharashstra.

Table 7 shows the decomposition of overall technical efficiency change (catch-up effect). During the entire period, out of 15 states, 11 exhibit the presence of catch-up effect (positive change in OTECH). In four states the contribution of change in PTE was zero, while in another two this effect was negative. The remaining 9 states witnessed a positive change. In the pre-reform period, the highest catch-up effect was in Orissa, whereas in Andhra Pradesh it was noticed during the post-reform years. In Orissa, the change in scale of production and improvement in PTE equally contributed to the positive effect, while in Andhra Pradesh the positive changes were due to improvement in scale effects only.

Table 8 provides the decomposition of technical change into pure and input-biased changes. The table also provides the annual average estimates of change in capital-labour ratio. During the pre-reform period, Uttar Pradesh exhibits the highest growth in the pure technical change (3.2 percent) followed by Orissa (1.7 percent) and Rajashtan (1.7 percent). It is Assam which records the highest negative change in the magnitude of pure technical change during the decade of 1980s. In the decade of 1990s, Orissa (9.3 percent), Rajasthan (8.7 percent), Madhya Pradesh (8.2 percent), Uttar Pradesh (8 percent), Gujarat (6.1 percent) and Bihar (4.6 percent) had the highest growth rates in pure technical progress. During this decade, seven states witnessed a negative change in pure technical progress, while Maharashtra and Punjab, experienced stagnation.

Recall that if capital-labour ratio increases and IBTECH<1, then it implies capital-using technical bias. On the other hand, IBTECH>1 implies labour-using technical bias. If the capital-labour ratio decreases, then IBTECH<1 indicates labour-using bias and IBTECH>1 shows capital-using technical bias. In the present analysis except for 1991-92, 1997-98 and 2000-01, capital-labour ratio has increased over its previous year (Table 5). During the pre-reform era, the average annual change in the capital ratio was 6.2 percent, whereas it was 9.4 percent during the post-reform period. Moreover, during both of the periods, the value of IBTECH was less than unity implying the presence of capital using technical bias in Indian manufacturing. This finding concurs with the finding of Pradhan and Barik (1999). Pradhan and Barik also finds the absence of labour-using technical progress in Indian manufacturing. Moreover, the manufacturing sector exhibits neutral technical bias for two years (1987-88 and 1994-95) and labour-using technical bias for four years. But we do not observe any consistent trend in input biased technical change either in favour of capital or labour (Table 5).

State-wise picture of the change in technical bias can be judged from Table 8. The table reveals that all the states witnessed an increase in average capital-labour ratio. In the post-reform era, all except Kerala, exhibit capital-using technical bias. In Kerala the technical bias was almost neutral. The finding on capital-using technical bias of the 1990s is a significant departure from the preceding decade when seven out of 15 states (Karnataka, Kerala, Madhya Pradesh, Orissa, Punjab, Rajasthan and West Bengal) exhibited almost neutral technical progress. In one of the states (Uttar

Pradesh), however, technical progress was slightly in favour of labour.

Innovative States and Convergence

It should be noted that the technical progress change index for any particular state between two adjacent years merely depicts the shift in the isoquant at the output level observed for that state. A value of technical change index less than unity does not necessarily imply that the state under consideration did actually push the overall isoquant inward. Thus in order to determine the states that were shifting the frontier or were 'innovators' (*see* Fare *et al.,* 1994), the following three conditions are required of various input distance functions for a given state k':

(a) $TECH_t^{t+1} < 1$;

(b) $D_i^t\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\right) < 1$;

(c) $D_i^{t+1}\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\right) = 1$.

The condition (a) indicates that the isoquant shifts in case of fewer inputs for the given level of output. With a given output vector, in period t+1 it is possible to decrease input bundle relative to period t. This measures the shift in the relevant portions of the isoquant between periods t and t+1 for a given state. The condition (b) indicates the production in period t+1 that occurs outside the isoquant of period t (i.e., technical change has occurred). It implies that the technology of period t is incapable of producing the output vector of period t+1 with the input vector of period t+1. Hence the value of input distance function $\left(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}\right)$ relative to the reference technology of period t is less than one. The condition (c) specifies that the state must be on the isoquant in period t+1.Table 9 shows the states that were innovator. Out of 18 two-year periods, Maharashtra and Assam shifted the isoquant five times each, while Bihar achieved the feat thrice and Gujarat twice.

In a recent study Aghion *et al*. (2003) finds that pro-market reform give rise to larger increase in productivity in the states that were closer to the frontier when the reforms were initiated. So, the growth enhancing effect should be smaller for the representative firm in the state that is farther from the frontier. On the other hand, the convergence theory could be restated in terms of the relationship between productivity and technical inefficiency. Such a relationship would state that the states that were near the production frontier would record a lower level of productivity growth than those farther away. Therefore, the positive relationship between productivity level and lagged technical inefficiency would indicate the presence of convergence hypothesis (Lall *et al.*, 2002).

In the present exercise we find that the states that were closer to the frontier in the efficiency estimation at the beginning of post-reform are not having the higher growth rate in TFP index. The correlation coefficient between the technical efficiency scores in 1991-92 and cumulative Malmquist index in 2000-01 (assuming that the value of Malmquist index is unity in 1991-92) is 0.22, which is statistically significant at 95 percent level of confidence interval. Moreover, we find that the states that were farther from the frontier in 1991-92 have gained not only due to increase in technical efficiency but also have experienced the higher growth rate of technical progress. This indicates that there is a tendency towards convergence in the productivity growth rates across states. This finding concurs with Ray (2002) and does not conform to Aghion *et al*. Here, it should be noted that if a state is technically efficient and is on the production frontier, then it is maximising its productive potential and there is little to be gained from adopting technology or knowledge from elsewhere. But only the states that were technically efficient were innovative in the sense that they were able to shift the isoquant inwards (*see* Table 9). It implies that although there is a tendency of convergence in manufacturing productivity growth among Indian states during the post-reform period, only those that are efficient at the beginning of the reform remain innovative.

IV. Conclusions

In this paper we use state level data on manufacturing from the Annual Survey of Industries for the years 1982-93 through 2000-01 to measure the Malmquist index of productivity growth. The index is also decomposed into technical change and efficiency change. The efficiency change is further decomposed into pure technical efficiency and input scale efficiency changes. The technical change is decomposed into magnitude of pure technical change and input-biased technical change. Such a decomposition of technical change helps in identifying the directions of biases in favour of labour or capital.

We found that in the pre-reform period TFP had grown at the rate of 1.7 percent per year while in the post-reform era the corresponding growth rate was 3 percent. While pre-reform period's growth rate in TFP was due to gains in technical efficiency, in the post-reform era it was influenced by the technical progress. Another interesting result of the present exercise is the nature of technical progress in Indian manufacturing. It was seen that the capital intensity of Indian firms is increasing in the recent years.

Although regional differences in TFP persist, it appears that the variation has declined in the post reform period. Majority of the states tried to be nearer to the isoquant in post-reform era in comparison to the pre-reform years. Most of the states are also operating under the increasing returns to scale and the gain in TFP in the post-reform era was due to gain in technical progress. In contrast, in the pre-reform period it was due to efficiency improvement. During the 1990s, capital intensity of the manufacturing sector seemed to have increased as the technical progress was in favour of capital. The states which were exhibiting either neutral or labour-using technical bias in the pre-reform period also show capital-using technical change during the post-reform era. It is also found that although there is a tendency of convergence in terms of TFP growth rate among Indian states during the post-reform era, only those that were technically efficient at the beginning of the reform remained innovative.

Beyond measuring of state TFP growth rates, the present analysis demonstrates the richness of linear programming technique that allows for an investigation of important research questions on the underlying processes that influence TFP growth. Notwithstanding the striking feature of the techniques used here, data limitations involved in estimation remains an important factor. It is, therefore, necessary to be cautious while applying these results to policy formulation.

References

Afriat, S. N. 1972. "Efficiency Estimation of Production Function", *International Economic Review,* 13: 568-98.

Aghion, P., R. Burgess, S. Redding, and F. Zilibotti, 2003. "The Unequal Effects of Liberalization: Theory and Evidence from India", Unpublished, London School of Economics, London.

Ahluwalia, I.J. 1991. *Productivity and Growth in Indian Manufacturing*, New Delhi: Oxford University Press.

Ahluwalia, I.J. 1995. "India: Industrial Development Review," The Economist Intelligence Unit and UNIDO.

Balakrishnan, P., and K. Pushpagandan, 1994. "Manufacturing Industry: A Fresh Look," *Economic and Political Weekly*, October: 2028-35.

Binswanger, H. 1974. "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution", *American Journal of Agricultural Economics,* 56: 377–86.

Burgess, R., and A. J. Venables, 2003. "Towards a Microeconomics of Growth", London School of Economics, London (mimeo).

Caves, D.W., L.R. Christensen, and W.E. Diewert, 1982. "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity", *Econometrica*, 50: 1993-40.

Das, D. K. 2003. "Quantifying Trade Barriers: Has Trade Protection Declined Substantially in Indian Manufacturing," Working Paper No. 105, Indian Council for Research on International Economic Relations, New Delhi.

Fare, R., E. *et.al.,* 1997. "Biased Technical Change and Malmquist Productivity Index" *Scandinavian Journal of Economics,* 99: 119-27.

Fare, R., S. Grosskopf, C. A. K. Lovell, 1994. *Production Frontiers.* Cambridge: Cambridge University Press.

Fare, R., *et.al*., 1994. "Productivity Growth, Technical Progress, and Efficiency Change in Industrialised Countries" *American Economic Review*, 84(1): 66-83.

Fare, R., S. Grosskopf, and W.F. Lee, 1995. "Productivity and Technical Change: The Case of Taiwan", Southern Illinois University (mimeo).

Fare, R. and D. Primont, 1995. *Multi-Output Production and Duality: Theory and Applications.* Boston: Kluwer Academic Publishers, Boston.

Foster, A. D., and M.R. Rozenzweig, 2003. “Agricultural Development, Industrialization and Rural Inequality,” unpublished, Harvard University, Cambridge, Massachusetts.

Goldar, B. N. 1986. *Productivity Growth in Indian Industry.* New Delhi: Allied Publishers.

Goldar, B. N. 2004. "Productivity Trends in Indian Manufacturing in the Pre and Post Reform Periods," Working Paper No. 137, Indian Council for Research on International Economic Relations, New Delhi.

Griliches, Z. and V. Ringstad, 1971. *Economies of Scale and Form of the Production Function.* Amsterdam: North-Holland Publishing Company.

Grosskopf, S. (1986) "The Role of the Reference Technology in Measuring Productive Efficiency", *The Economic Journal,* 96: 499–513.

Hossain, M. A. and N. D. Karunaratne, 2004. "Trade Liberalization and Technical Efficiency: Evidence from Bangladesh Manufacturing Industries" *The Journal of Development Studies,* 40(3): 87-114.

Lall, P., A.M. Featherstone and D.W. Norman, 2002. “Productivity Growth in the Western Hemisphere (1978-94): the Caribbean in Perspective”, *Journal of Productivity Analysis,* 17: 213-231.

Pradhan, Gopinath and K. Barik, 1999. "Sustainability of Output Growth in Indian Manufacturing: A Decomposition Analysis of Selected Industries", Paper presented at the 1999 Annual meeting of the Australian Econometric Society, University of Technology, Sydney.

Ray, S.C. 1997. "Regional Variation in Productivity Growth in Indian Manufacturing: A Non-parametric Analysis", *Journal of Quantitative Economics,* 13: 73-94.

Ray, S.C. (2002) "Did India's Economic Reforms Improve Efficiency and Productivity? A Non-parametric Analysis of the Initial Evidence from Manufacturing", *Indian Economic Review,* 37: 23-57.

RBI 2004. *Report on Currency and Finance*, 2002-03, New Delhi.

Rodrik, Dani and Arvind Subramanian, 2004. "From 'Hindu Growth' to Productivity Surge: The Mystery of the Indian Growth Transition", IMF Working Paper WP/04/77, International Monetary Fund, Washington DC.

Salim, R.A. and K. P. Kalirajan, 1999. "Sources of Output Growth in Bangladesh Food Processing Industries: A Decomposition Analysis" *The Developing Economies,* 37: 355-374.

Unel, B. 2003. "Productivity Trends in India's Manufacturing Sectors in the Last Two Decades," IMF Working Paper, WP/03/22, International Monetary Fund, Washington DC.

Weber, W.L. and B. R. Domazlicky, 1999. "Total Factor Productivity Growth in Manufacturing: A Regional Approach Using Linear Programming" *Regional Science and Urban Economics,* 29: 105-122.

Table 2: Efficiency Results, Geometric Means (yearwise)

Year	Overall Technical Efficiency	Pure Technical Efficiency	Input Scale Efficiency
1982-83	1.448	1.257	1.317
1983-84	1.273	1.160	1.235
1984-85	1.310	1.130	1.289
1985-86	1.507	1.176	1.498
1986-87	1.348	1.150	1.340
1987-88	1.338	1.125	1.310
1988-89	1.437	1.179	1.417
1989-90	1.422	1.131	1.407
1990-91	1.414	1.105	1.374
1991-92	1.296	1.079	1.281
1992-93	1.391	1.120	1.346
1993-94	1.505	1.149	1.505
1994-95	1.369	1.132	1.346
1995-96	1.282	1.102	1.274
1996-97	1.282	1.103	1.281
1997-98	1.343	1.071	1.332
1998-99	1.316	1.154	1.310
1999-00	1.361	1.145	1.343
2000-01	1.275	1.089	1.249
Pre-reform	1.387	1.156	1.352
Post- reform	1.340	1.114	1.325
Overall	1.362	1.134	1.338

Table 3: Efficiency Results, Geometric Means (statewise)

States	Overall Technical Efficiency			Pure Technical Efficiency			Input Scale efficiency		
	Overall	Pre-reform	Post-reform	Overall	Pre-reform	Post-reform	Overall	Pre-reform	Post-reform
Andhra Pradesh	1.840	1.917	1.773	1.032	1.011	1.052	1.824	1.917	1.744
Assam	1.037	1.002	1.070	1.017	1.000	1.033	1.035	1.002	1.066
Bihar	1.120	1.126	1.114	1.074	1.029	1.117	1.068	1.048	1.086
Gujarat	1.218	1.264	1.173	1.042	1.069	1.017	1.217	1.262	1.173
Haryana	1.371	1.445	1.301	1.209	1.252	1.168	1.361	1.435	1.292
Karnataka	1.196	1.286	1.112	1.097	1.134	1.062	1.194	1.282	1.112
Kerala	1.376	1.364	1.429	1.127	1.204	1.061	1.365	1.352	1.429
Madhya Pradesh	1.303	1.278	1.329	1.190	1.164	1.216	1.203	1.169	1.237
Maharashtra	1.019	1.013	1.025	1.000	1.000	1.001	1.012	1.000	1.025
Orissa	1.482	1.548	1.419	1.352	1.388	1.318	1.413	1.480	1.350
Punjab	1.775	1.935	1.629	1.105	1.119	1.090	1.775	1.935	1.629
Rajasthan	1.501	1.568	1.438	1.158	1.305	1.027	1.490	1.544	1.438
Tamil Nadu	1.354	1.281	1.432	1.052	1.078	1.027	1.354	1.281	1.432
Uttar Pradesh	1.527	1.690	1.379	1.265	1.406	1.138	1.520	1.676	1.379
West Bengal	1.642	1.482	1.819	1.476	1.302	1.674	1.541	1.315	1.805

Table 4: Returns to Scale in States

Year	Constant Returns to Scale	Decreasing Returns to Scale	Increasing Returns to Scale
1982-83	TN	BIH, GUJ, HAR, KAR, KER, MP, MAH, ORI, RAJ, UP, WB	AP, ASS, PUN,
1983-84	ASS, BIH, MAH, TN	MP, WB	AP, GUJ, HAR, KAR, KER, ORI, PUN, RAJ, UP
1984-85	ASS, MAH	WB	AP, BIH, GUJ, HAR, KAR, KER, MP, ORI, PUN, RAJ, TN, UP
1985-86	ASS, MAH	-	AP, BIH, GUJ, HAR, KAR, KER, MP, ORI, PUN, RAJ, TN, UP, WB
1986-87	ASS, MAH	-	AP, BIH, GUJ, HAR, KAR, KER, MP, ORI, PUN, RAJ, TN, UP, WB
1987-88	ASS, MAH	BIH, MP, WB	AP, GUJ, HAR, KAR, KER, ORI, PUN, RAJ, TN, UP
1988-89	ASS, GUJ	BIH, MP, MAH, ORI	AP, HAR, KAR, KER, PUN, RAJ, TN, UP, WB
1989-90	ASS, MAH	BIH, ORI	AP, GUJ, HAR, KAR, KER, MP, PUN, RAJ, TN, UP, WB
1990-91	ASS, MAH	MP, ORI	AP, BIH, GUJ, HAR, KAR, KER, PUN, RAJ, TN, UP, WB
1991-92	BIH, KAR, MAH	ORI	AP, ASS, GUJ, HAR, KER, MP, PUN, RAJ, TN, UP, WB
1992-93	KAR, MAH	MP, ORI	AP, ASS, BIH, GUJ, HAR, KER, PUN, RAJ, TN, UP, WB

Year	Constant Returns to Scale	Decreasing Returns to Scale	Increasing Returns to Scale
1993-94	ASS, BIH	-	AP, GUJ, HAR, KAR, KER, MP, MAH, ORI, PUN, RAJ, TN, UP, WB
1994-95	KAR, MAH	MP	AP, ASS, BIH, GUJ, HAR, KER, ORI, PUN, RAJ, TN, UP, WB
1995-96	ASS, MAH	MP	AP, BIH, GUJ, HAR, KAR, KER, ORI, PUN, RAJ, TN, UP, WB
1996-97	BIH, GUJ, KAR	KER, MAH, ORI	AP, ASS, HAR, MP, PUN, RAJ, TN, UP, WB
1997-98	BIH	ORI	AP, ASS, GUJ, HAR, KAR, KER, MP, MAH, PUN, RAJ, TN, UP, WB
1998-99	ASS, BIH, GUJ, MAH	ORI	AP, HAR, KAR, KER, MP, PUN, RAJ, TN, UP, WB
1999-00	ASS, MAH	BIH	AP, GUJ, HAR, KAR, KER, MP, ORI, PUN, RAJ, TN, UP, WB
2000-01	MAH	BIH, MP	AP, ASS, GUJ, HAR, KAR, KER, ORI, PUN, RAJ, TN, UP, WB

Note: Andhra Pradesh (AP), Assam (ASS), Bihar (BIH), Gujarat (GUJ), Haryana (HAR), Karnataka, (KAR), Kerala (KER), Madhya Pradesh (MP), Maharashtra (MAH), Orissa (ORI), Punjab (PUN), Rajasthan (RAJ), Tamilnadu (TN), Uttar Pradesh (UP) and West Bengal (WB)

Table 5: Malmquist Productivity Index and its Decomposition, Geometric Means (yearwise)

Year	OTE-CH	PTEC	ISEC	IBTE-CH	MATE-CH	TE-CH	MALM	$(K/L)^{T+1}/(K/L)^{T}$
1983-84	0.879	0.923	0.938	1.005	1.155	1.161	1.021	1.131
1984-85	1.029	0.974	1.044	0.987	0.980	0.967	0.995	1.105
1985-86	1.151	1.040	1.163	0.996	0.851	0.847	0.975	1.065
1986-87	0.894	0.978	0.895	0.989	1.076	1.064	0.952	1.092
1987-88	0.992	0.978	0.978	1.001	1.014	1.016	1.008	1.059
1988-89	1.074	1.048	1.082	0.989	0.841	0.831	0.893	1.015
1989-90	0.990	0.959	0.993	0.993	1.024	1.017	1.006	1.012
1990-91	0.994	0.977	0.977	0.988	0.978	0.967	0.961	1.116
1991-92	0.917	0.976	0.932	0.995	1.149	1.144	1.048	0.972
1992-93	1.073	1.038	1.050	0.979	0.945	0.925	0.993	1.079
1993-94	1.082	1.026	1.119	0.983	0.900	0.884	0.957	1.101
1994-95	0.910	0.985	0.894	1.001	1.096	1.097	0.998	1.048
1995-96	0.936	0.974	0.946	0.993	1.054	1.047	0.980	1.161
1996-97	1.000	1.001	1.005	0.999	1.001	1.000	0.999	1.074
1997-98	1.048	0.971	1.040	0.996	0.931	0.927	0.971	1.121
1998-99	0.980	1.077	0.983	0.988	1.001	0.989	0.969	0.973
1999-00	1.034	0.992	1.025	0.958	0.799	0.766	0.792	1.435
2000-01	0.937	0.951	0.929	0.991	1.183	1.173	1.098	0.927

Year	OTE-CH	PTEC	ISEC	IBTE-CH	MATE-CH	TE-CH	MALM	$(K/L)^{T+1}/(K/L)^{T}$
Pre-reform	0.988	0.983	0.997	0.994	1.002	0.996	0.983	1.062
Post-reform	0.998	1.001	0.997	0.988	0.984	0.972	0.970	1.094
Overall	0.993	0.992	0.997	0.991	0.993	0.984	0.977	1.078

Note: OTECH: Overall technical efficiency change index; PTEC: Pure technical efficiency change index; ISEC: Input scale efficiency change index; IBTECH: Input biased technological change index; MATECH: Magnitude of pure technological change index; TECH: technological change index; MALM: Malmquist productivity index; $(K/L)^{T+1}/(K/L)^{T}$: Change in capital-labour ratio over previous year.

Table 6: Decomposition of Malmquist Index: Average Annual Percentage Changes (statewise)

States	Overall			Pre-reform			Post- reform		
	OTECH	TECH	MALM	OTECH	TECH	MALM	OTECH	TECH	MALM
Andhra Pradesh	0.662	-0.809	-0.142	-4.666	-0.214	-4.890	5.719	-1.409	4.391
Assam	-1.360	-3.511	-4.918	-0.204	-2.210	-2.418	-2.529	-4.828	-7.479
Bihar	0.663	3.599	4.238	2.838	1.686	4.477	-1.561	5.475	3.999
Gujarat	1.224	4.504	5.673	-0.618	1.392	0.783	3.031	7.518	10.321
Haryana	0.071	1.063	1.133	-0.251	0.656	0.407	0.391	1.469	1.854
Karnat-aka	-0.043	-1.096	-1.139	2.376	-0.310	2.073	-2.522	-1.887	-4.457
Kerala	0.635	-2.137	-1.488	-0.003	0.089	0.086	1.270	-4.412	-3.086
Madhya Pradesh	1.602	5.371	6.887	2.413	1.653	4.026	0.785	8.949	9.663
Maharashtra	0.472	2.757	3.217	0.943	0.425	1.363	0.000	5.035	5.035
Orissa	2.584	5.693	8.130	8.188	1.734	9.780	-3.362	9.492	6.449
Punjab	2.475	-0.080	2.397	3.218	-0.072	3.148	1.727	-0.088	1.640
Rajasthan	3.440	5.522	8.772	6.201	1.664	7.763	0.598	9.228	9.771
Tamil Nadu	-1.217	-1.667	-2.905	-3.363	-1.987	-5.417	0.884	-1.349	-0.453
Uttar Pradesh	0.954	5.610	6.511	4.741	2.477	7.101	-2.983	8.642	5.917
West Bengal	-1.726	-1.072	-2.817	-4.488	-0.480	-4.990	0.963	-1.667	-0.689

Note: OTECH: Overall technical efficiency change index; TECH: Technological change index; MALM: Malmquist productivity index.

Table 7: Decomposition of Efficiency Change Index, Geometric Means (statewise)

States	Overall			Pre-reform			Post- reform		
	OTECH	PTEC	ISEC	OTECH	PTEC	ISEC	OTECH	PTEC	ISEC
Andhra Pradesh	0.993	0.995	0.993	1.047	0.990	1.047	0.943	1.000	0.943
Assam	1.014	1.008	1.014	1.002	1.000	1.002	1.025	1.016	1.025
Bihar	0.993	1.000	1.000	0.972	1.000	1.000	1.016	1.000	1.000
Gujarat	0.988	0.983	0.989	1.006	0.969	1.008	0.970	0.998	0.970
Haryana	0.999	0.998	1.003	1.003	0.999	1.009	0.996	0.996	0.996
Karnataka	1.000	0.997	1.001	0.976	0.978	0.978	1.025	1.016	1.025
Kerala	0.994	0.983	0.994	1.000	0.976	1.001	0.987	0.991	0.987
Madhya Pradesh	0.984	1.000	1.000	0.976	1.023	1.027	0.992	0.977	0.974
Maharashtra	0.995	1.000	1.000	0.991	1.000	1.000	1.000	1.000	1.000
Orissa	0.974	0.980	0.983	0.918	0.923	0.923	1.034	1.042	1.046
Punjab	0.975	0.978	0.975	0.968	0.965	0.968	0.983	0.990	0.983
Rajasthan	0.966	0.961	0.973	0.938	0.928	0.952	0.994	0.996	0.994
Tamil Nadu	1.012	1.000	1.012	1.034	1.000	1.034	0.991	1.001	0.991
Uttar Pradesh	0.990	0.978	0.995	0.953	0.949	0.961	1.030	1.009	1.030
West Bengal	1.017	1.019	1.026	1.045	1.054	1.054	0.990	0.986	0.998

Note: OTECH: Overall technical efficiency change index; PTEC: Pure technical efficiency change index; ISEC: Input scale efficiency change index.

Table 8: Decomposition of Technological Change, Geometric Means (statewise)

States	Overall				Pre- reform				Post-reform			
	IBTECH	MATECH	TECH	$(K/L)^{T+1}/(K/L)^{T}$	IBTECH	MATECH	TECH	$(K/L)^{T+1}/(K/L)^{T}$	IBTECH	MATECH	TECH	$(K/L)^{T+1}/(K/L)^{T}$
Andhra Pradesh	0.994	1.015	1.008	1.092	0.994	1.008	1.002	1.165	0.993	1.021	1.014	1.023
Assam	0.961	1.077	1.035	1.128	0.965	1.060	1.022	1.150	0.958	1.094	1.048	1.106
Bihar	0.994	0.970	0.964	1.048	0.998	0.985	0.983	1.050	0.989	0.956	0.945	1.046
Gujarat	0.986	0.969	0.955	1.120	0.987	1.000	0.986	1.121	0.985	0.939	0.925	1.119
Haryana	0.985	1.004	0.989	1.094	0.993	1.001	0.993	1.118	0.978	1.008	0.985	1.070
Karnataka	0.998	1.013	1.011	1.103	1.002	1.001	1.003	1.092	0.994	1.025	1.019	1.115
Kerala	1.002	1.020	1.021	1.067	0.997	1.002	0.999	1.093	1.006	1.038	1.044	1.042
Madhya Pradesh	0.995	0.951	0.946	1.041	0.998	0.985	0.983	1.071	0.992	0.918	0.911	1.012
Maharashtra	0.963	1.010	0.972	1.094	0.977	1.020	0.996	1.126	0.949	1.001	0.950	1.063
Orissa	0.999	0.944	0.943	1.099	1.000	0.983	0.983	1.167	0.997	0.907	0.905	1.035
Punjab	0.998	1.003	1.001	1.064	0.997	1.003	1.001	1.122	0.998	1.002	1.001	1.010
Rajasthan	0.997	0.947	0.945	1.066	1.000	0.983	0.983	1.084	0.995	0.913	0.908	1.049
Tamil Nadu	0.994	1.023	1.017	1.097	0.989	1.031	1.020	1.136	0.998	1.016	1.013	1.060
Uttar Pradesh	1.000	0.944	0.944	1.077	1.008	0.968	0.975	1.116	0.993	0.920	0.914	1.039
West Bengal	0.996	1.014	1.011	1.077	1.003	1.002	1.005	1.125	0.990	1.027	1.017	1.030

Note: IBTECH: Input biased technological change Index; MATECH: Magnitude of pure technological change index; TECH: Technological change Index; MALM: Malmquist productivity index; $(K/L)^{T+1}/(K/L)^{T}$: Change in capital-labour ratio over previous year.

Table 9: States Causing Inward Shift in Isoquant Over the Previous Year

Year	States
1983-84	-
1984-85	Maharashtra
1985-86	Assam, Maharashtra
1986-87	-
1987-88	Assam
1988-89	Assam, Gujarat
1989-90	-
1990-91	Maharashtra
1991-92	-
1992-93	Maharashtra
1993-94	Bihar, Assam
1994-95	-
1995-96	-
1996-97	Gujarat, Bihar
1997-98	Bihar
1998-99	Assam
1999-00	Maharashtra
2000-01	-

Endnotes

[1] The fifteen major states are Andhra Pradesh (AP), Assam (ASS), Bihar (BIH), Gujarat (GUJ), Haryana (HAR), Karnataka (KAR), Kerala (KER), Madhya Pradesh (MP), Maharashtra (MAH), Orissa (ORI), Punjab (PUN), Rajasthan (RAJ), Tamilnadu (TN), Uttar Pradesh (UP) and West Bengal (WB). These fifteen major states account for approximately 95 percent of population and industrial output in the country and are therefore representative.

[2] The firm level input-output pairs are feasible, although not individually reported. Therefore, by the assumption of convexity, the average input-output bundle will always be feasible. The aggregate input-output bundle will be feasible only under the condition of additivity of technology (Ray, 2002).

[3] To the extent that price indices at the state levels deviate from the All-India indices, the non-labour variables for individual states will be distorted. But non-availability of price indices at the individual state level precluded a more refined construction of data.

[4] The terms pre-reform and pro-business reform are used synonymously as they refer to same period in the present study. Like that the terms post-reform and pro-market are used synonymously in the present study.

[5] If $T^{CRS}=T^{VRS}$ the state operates in the range of constant returns to scale (CRS). If $T^{CRS}\neq T^{VRS}=T^{NRS}$ the state operates in the range of decreasing returns to scale (DRS). Finally, if $T^{CRS}=T^{NRS}<T^{VRS}$ the state operates in the range of increasing returns to scale (IRS).

[6] The disaggregated results for each state and year can be had from the author on request.