Measuring and Decomposing Sources of Productivity Performance in India's Paper and Pulp Industry under Liberalized Regime: A Nonparametric Approach

Sarbapriya Ray[1]

Abstract

The purpose of this study is to develop a methodology in measuring productivity growth by decomposing it into technical change and technical efficiency change in India's paper industry. The prime objective of this article is to assess the impact of liberalization on productivity growth of India's paper industry. Specifically, this study quantifies the level of technical efficiency and technical change in this particular manufacturing sector. The paper applies Malmquist Productivity Index method to different sub-sectors of India's Paper and pulp industry at aggregate level in order to have trend in productivity growth covering a period of 28 years commencing from 1979-80 to 2006-07. Finally, regressing the log difference of the measured productivity growth on the log difference of the capacity utilization rate which is a proxy for business cycle, attempt has been made to find out capacity utilization adjusted TFP growth. The result of this study reveals decline in growth rate of TFP during post-reforms (1991-92 to 2006-07) period showing adverse impact of liberalization at aggregate level. Results also indicate that during the study period, industry also experienced regress in technological progress along with stagnation in technical efficiency. Non-responding technical efficiency change and the deteriorating technical change were the main ingredients responsible for declining productivity change in Indian paper and pulp industry. Moreover, removal of short run variations in capacity utilization from the estimated TFP growth hardly affects its overall movement but remarkably mitigates its variation because variations between sub-periods are lesser after adjusting capacity utilization as cyclical factor.

Keywords: Indian Paper Industry, Total Factor Productivity, Economic Reforms, Malmquist Index, Data Envelopment Analysis

JEL classification: L60, O25, D24

1. Introduction

Productivity growth is considered indispensable to produce higher quality goods in a more efficient manner which results in lower cost to consumers and also to raise per

[1] Department of Commerce, Shyampur Siddheswari Mahavidyalaya University of Calcutta, India, e-mail: sarbapriyaray@yahoo.com

capita incomes over time. Every industry is continuously in a process of self-appraisal and in search of tools for measuring its own current performance in comparison with the various targets, past achievements and productivity growth. Business decision and policy formulation mostly depend on such economic indicators. Total factor productivity (TFP) is comprehensively recognized as an advanced indicator of industrial performance as compared to labour productivity and multi-factor productivity for characterizing industry-level productivity performance. Estimating productivity level and growth rate as well as analyzing productivity determinants to evaluate the efficiency in use of resources in the industry gained a renewed interest among economists. Theoretically, TFP is a relevant measure for technological change by measuring the real growth in production value, which cannot be explained by changes in the input that is, labour, capital and intermediate input. However in reality, most works on TFP measurement are limited on the basis of two factor inputs- capital and labour. But, the increasing role of materials inputs in productivity has compelled researchers to reconstruct their productivity measurement model to incorporate all factor inputs, labour, capital and intermediate inputs.

2. Literature Review

Empirical studies suggest that trade reforms promoted total factor productivity (TFP) in Indian manufacturing during 1980s (Goldar, 1986; Ahluwalia, 1991; Chand, and Sen, 2002). There is adequate reason to suppose that manufacturing sector responds to liberalization and the high growth rate during 1990s was 'due to continued structural reforms including trade liberalization, leading to efficiency gains'. (WTO, 2001, p. 1). This view has been supported by Krishna and Mitra (1998) and Unel (2003) who found that growth of TFP was higher in 1990s compared. Turning to the trends in productivity in the post-reform period, the evidence from empirical studies by researchers was ambiguous, though subjective evidence, especially of trends of recent years shows significant increases in productivity growth. Tata Service Ltd (TSLs, 2003) has reported a faster growth rate in TFP in Indian manufacturing in post-reform period as compared to pre-reform period. Despite ambiguity regarding acceleration in TFPG, evidence suggests that trade liberalization since 1991 had a positive impact on the TFPG in India (Krishna and Mitra, 1998; Chand and Sen, 2002; Topalova, 2004).

Several studies find TFP growth in Indian manufacturing deteriorated during 1990s compared with that of 1980s. (Das, 1999; 2003; Singh et al., 2000; Srivastav, 2001; Goldar and Kumari, 2003). Balakrishnan et al. (2000) reports a significant decline in the growth rate of TFP since 1991-92 in five manufacturing industries in India but they failed to find a link between trade reform and TFP growth. Most of the studies on productivity in India have focused on the growth in TFP in Indian manufacturing. Other studies suggest a decline in total factor productivity growth until 1970s, with a turnaround taking place in mid 1980s, pursuant to the reoriented trade and industrial policies and improved infrastructure performance (Brahmananda, 1982; Ahluwalia, 1991; Balakrishnan and Pushpangadan, 1994; Majumder, 1996; Rao, 1996; Pradhan and Barik, 1999). The proposition that the

TFPG accelerated during the 1980s would be consistent with the recent debatable view associated with Rodrik and Subramanian (2004) who argued that transition to high growth phase occurred around 1980- a full decade before economic liberalization-that started being adopted during the 1980s. Given this ambiguity, the effect of trade reforms on total factor productivity growth is an empirical issue. Goldar and Kumari (2003) analyzed the impact of liberalization on the productivity growth of Indian manufacturing industries and found productivity accelerated in paper, paper products, printing and publishing industry in the 1990s. Pattnayak and Thangavelu (2005) studied the economic reform and productivity growth in Indian manufacturing, including paper and paper products industry and found a little increase in the growth of TFP of paper and paper product industry during post-reform period. Sindhu and Balasubramanyam (2006) computed Malmquist index of productivity growth of Indian paper and paper products industry during pre-reform period. The rate of growth was 3.1 per cent and this was due to the improvement in technical change. Kiran and Kaur (2008) estimates the trend in output (value added) and inputs (labour, capital) as well as partial productivity and total factor productivity for all India manufacturing at aggregative as well as disaggregate level for twenty two industry groups. Their study applies translog function using the data from Annual Survey of Industries (ASI) by Central Statistical organization, Government of India for the analysis. The comparative picture of their study during pre-liberalization and post-liberalization period depict a slower growth of manufacturing sector of India in the post-reform era for aggregative and disaggregate level.

In view of the above literature review, it has been established that although there have been voluminous studies carried on upon productivity growth, relatively a small number of studies have been conducted so far in India regarding sources of productivity growth. The Malmquist index decomposes the total productivity growth into 'efficiency change' and 'technical progress'. TFP can be increased by using its existing technology and factor inputs more efficiently which is termed as 'efficiency change'. The TFP of an industry may enhance if the industry adopts innovations or technological improvements, which is referred to as 'technological change'. Therefore, changes in TFP from one period to the next are the products of both efficiency change and technological progress. Most previous studies conducted in India have failed to consider the sources of such changes in productivity growth.

The study aims at measuring productivity growth by decomposing it into technical change and technical efficiency change in India's paper industry and assessing the impact of liberalization on productivity growth of Indian Paper industry. Specifically, this study quantifies the level of technical efficiency and technical change in this particular manufacturing sector and examines trend in TFPG after adjusting economic capacity utilization.

The paper is organized as follows: Section 3 depicts the economic snapshot of Indian paper industry under liberalized regime, Section 4 depicts the methodology utilized to estimate the Malmquist productivity index. The result of productivity growth in Indian paper and pulp products industry is evaluated in Section 5. Section 6 analyses trend in TFPG after adjusting capacity utilization and section 7 presents summary and conclusion.

3. Economic Snapshot of Indian Paper and Pulp Industry under Liberalized Regime

In late 1970s, Government of India started implementing some reforms such as "reducing the barriers to entry and expansion, simplifying procedures, and providing easier access to better technology and intermediate material imports" (Ahluwalia, 1991). There were some additional reforms during 1980s, but the most radical reforms were initiated since 1991, after the severe economic crisis in the fiscal year 1990-91. The major policy changes initiated in the industrial sector since July 1991 include removal of entry barriers, reduction of areas reserved exclusively for public sector, rationalization of approach towards monopolistic and restrictive practice, liberalization of foreign investment policy, far reaching liberalization of import policy with respect to intermediate and capital goods, measures to bring about regional balance, especially the development of backward areas and encouraging the growth of employment intensive in small and tiny sector (Madheswaran et al., 2007).

Therefore, Indian economy was under the protected trade policy regime till July 24, 1991 and the policy measures were liberalised and entered in free trade regime after 1991. These two policies led to different impact on Indian manufacturing in general and Indian paper and paper products in particular. The Government of India has completely delicensed the paper industry with effect from July 1997. The Indian Paper industry is a priority sector for foreign collaboration and foreign equity participation up to 100 percent which receives automatic approval by Reserve Bank of India. Several fiscal incentives have also been provided to the paper industry, particularly to those mills which are based on non-conventional raw material.

The paper industry is the second industry which was liberalized in India after the cement industry. Much before initiation of liberalization process since July, 1991, the paper industry was partially de-licensed in 1984-85, especially the agro-based paper mills segment. Delicensing was extended to other segments of the industry in1991. Thus the industry has witnessed far-reaching policy changes starting from a controlled policy regime to a liberalized one. These changes have affected various fields of operations and given a more flexible approach to decision-making.

With the advent of economic liberalization and stricter environmental regulations, the promotion of larger more efficient paper mills has been initiated. Presently, large paper mills are more efficient, using better and more modern technologies and appropriating economies of scale. Additionally, they provide chemical recovery facilities which reduce both emissions and external energy requirements. However, the large paper mills also face severe basic problems such as high production costs, raw material constraints and low productivity. Overall performance has been best in medium size firms with regards to average profitability (Sharma et al., 1998).

Small and medium size paper mills became important when due to a severe paper shortage in the early 1970s, the government promoted the immediate establishment of small, readily available paper units. As a result of the paper shortage and overall government pricing policy, the small and medium sector with more than 300 paper mills accounted for almost 50% of installed capacity and production in 1992. They produce primarily low quality paper such as kraftpaper and paperboards from recycled paper and various agro-fibers. (Meadows, 1997; Sharma et al., 1998).Yet, the small units suffer from high production costs, uneconomic operation, low quality and negative impacts on the environment.

About 150 small mills were closed or sitting idle (Meadows, 1997). Already old when imported the units have further degraded since, which has led to the current situation of low productivity, low efficiency, excessive resource consumption, obsolete technologies, capacity underutilization and low scale of operation. International competition and the high quality and low production costs of imported paper will also force many small mills to close. Furthermore, most small and medium size pulp and paper mills cannot economically provide chemical recovery and pollution control systems. Therefore, they are highly polluting industries contributing substantially to the overall level of emissions and environmental problems. (Datt and Sundharam, 1998).

The paper industry in India is highly energy intensive. It is ranked sixth largest energy consumer in the country. The average energy cost for Indian paper mills is about 15–20 percent of total production cost, as against 10 percent in USA, Sweden, Finland, and other major paper producing countries. The Indian paper industry accounts for about 1.6 percent of the world's production of paper and paperboard and is expected to grow with an annual rate of 6-7 percent in near future. This sector provides employment to about 3.5million people directly and indirectly. The paper consumption in India is about 7 kg per capita as against the world average of 50 kg per capita (Central Pulp and Paper Research Institute, 2007). The total output of Indian paper industry is about 7.4 MT, with a turnover of about Rs 160 billion. It contributes about Rs 25 billion to the state and central exchequers by way of various duties and taxes. It is a capital-intensive, energy-intensive and pollution emitting industry. The Indian pulp and paper industry recorded a steady average annual growth rate of 5.47 percent over the past couple of years. Broadly, there are two types of paper products: paper and paper boards, and newsprint. Paper and paperboard can further be subdivided into industrial grade (wrapping and packaging, specialty, kraft etc.) and cultural (writing and printing) paper. Based on the installed capacity , the Indian mills are categorized into two types: (1) large mills(capacity > 100 tons per day) and (2) small mills(capacity < 100 tons per day).The number of large paper mills is less as compared to the small mills that account for 50 percent of the production capacity. The production of paper and paperboards increased from 5.56 million tons in 2003-'04 to 5.79 million tons in 2004-'05. At present, about 60.8 percent of the total production is based on non-wood raw materials (agriculture residue and waste papers) and 39.2 percent on wood. The supply and demand projection up to 2015-'16 are 10million tons and 13 million tons respectively, leading to a shortfall of 3 million tons. The growth rate of writing and printing varieties is expected to be 4-6percent per annum, while that of industrial paper is estimated to be 12 percent. The higher growth rate of industrial paper is due to the substitution of conventional packaging of products by paper and paper board. Imports of paper and paper products were growing over the years.

However, it has increased during 2001-‘02 after a fall in 2000-‘01. About 1,40,000 tons of paper was exported in 2000-‘01 mainly to the neighbouring countries.

There are 666 pulp and paper mills with installed capacity of 9.5 MT and production of 6.5 MT of paper and paperboard, and 0.9 MT of newsprint. The paper production can be classified on the basis of raw material—forest based (32%), non-wood based (30%), and waste paper based (38%).The large mills utilize, mainly, hardwood and bamboo, while the smaller ones use agro residue such as bagasse, wheat and rice straw, jute, and recycled fibers. The country is almost self-sufficient in manufacture of most varieties of paper and paperboards. Import, however, is confined only to certain specialty papers. To meet part of its raw material needs the industry has to rely on imported wood pulp and waste paper. Production of paper and paperboard during the year 2002-‘03 (up to December, 2002) is 24.52 million tons. At present about 60.8 per cent of the total production is based on non-wood raw material and 39.2 per cent based on wood.

4. Analytical Framework and Methodological Issues

4.1 Description of data and measurement of variables

The present study is based on industry-level as well as firm level time series data taken from several issues of Annual Survey of Industries, National Accounts Statistics, Center for Monitoring Indian Economy (*CMIE*) and Economic Survey, Statistical Abstracts (several issues), *RBI* Bulletin on Currency and Finance, Handbook of Statistics on Indian Economy, and Office of Economic Advisor, Ministry of Industry etc. Selection of time period is largely guided by availability of data[1]. In the ASI, the paper and paper products industry is conveniently classified under 3 sub-sectors for which consistent data are available, at three and four-digit industrial classification levels.

The output in the current model is the modified gross value of output(Y). It is defined as the total output produced by the firm. In order to avoid over estimation due to ignoring contribution of material input on TFP, a third variable of intermediate inputs (material including energy input, see, Appendix A1)[2] has been incorporated in the value-added function as such to obtain gross output. Pradhan and Barik (1999) argued that the gross output, instead of value added, appears to be the appropriate choice of TFPG estimation in India. Generally, TFP growth estimates based on value added terms are over estimated

[1] Till 1988 – 89, the classification of industries followed in ASI was based on the National Industrial classification 1970 (NIC, 1970). The switch to the NIC, 1987 from 1989-90 and also switch to NIC, 1998 requires some matching. Considering NIC, 1987 as base and further NIC, 1998 as base, Paper industry has been merged accordingly. For price correction of variable, wholesale price indices taken from official publication of CMIE have been used to construct deflators.

[2] Earlier studies that have not treated material including energy as separate factor of production, has failed to pick-up significant economies that are likely to generate in the use of such input. Jorgenson (1988) has observed that in a three input production framework, the contribution of intermediate inputs like material, energy etc. are significant sources of output growth.

since they ignore the contribution of intermediate inputs on productivity growth (Sharma, 1999). Therefore, modified gross value of output so calculated has been used as a measure of output. It has been suitably deflated by wholesale price index of manufactured and material, labour and fixed capital stocks are our aggregate input proxies. Total number of persons engaged in Indian paper and pulp sector is used as a measure of labor inputs. It is reported in ASI which includes production workers and non-production workers like administrative, technical and clerical staff (Goldar et al., 2004). Deflated gross fixed capital stock at 1981-82 prices is taken as the measure of capital input. The estimates are based on perpetual inventory method (see, Appendix A2). Following the same line as adopted in deflating energy input, the reported series on materials has been deflated to obtain material inputs at constant prices.

This paper covers a period of 28 years from 1979 -80 to 2006-07. The entire period is sub-divided into two phases as pre-reform period (1979 -80 to 1991-92) and post-reform period (1991-92 to 2006-07), sub-division of period being taken logically as such to assess conveniently the impact of liberalization on TFPG .

4.2 Non parametric approach to productivity measurement:

Data Envelopment Analysis (DEA) is a non-parametric approach of frontier estimation. The term DEA was invented by Charnes, Cooper and Rhodes (1978). DEA measures the relative efficiency of a set of firms. In production theory, there are two types of efficiency measures at the firm level. The first is the technical or production efficiency, which measures the level of success a firm has reached by producing maximum output from a given set of inputs. The second one is the price or allocated efficiency, which measures a firm's success in choosing an optimal set of inputs for a given set of input prices. DEA is a technique based on linear programming that places a non-parametric surface frontier (a piecewise linear convex isoquant) over data points to determine the efficiency of each firm in relation to the frontier. The aim of DEA is to estimate relative efficiency among similar decision units that have the same technology (processing procedure) to pursue similar objectives (outputs) by using similar resources (inputs). The higher efficiency is denoted by one, while the lowest is denoted by zero. DEA constructs the production-possibilities frontier from the data by using linear programming. The efficiency of a firm, or a decision making unit (DMU) as firms are called in most DEA literature, using "n" different inputs to produce "m" outputs, is measured as the ratio of weighted outputs to weighted inputs. Once the frontier is constructed, the measure of efficiency for any DMU is derived by comparing Euclidean distances from points on the frontier, with corresponding distances from the axis to points which are below the frontier. DMUs that lie on the frontier are efficient, while DMUs under the frontier are considered inefficient, since they use the same level of inputs but produce less output, or have the same output but employ more inputs.

Data Envelopment Analysis in a linear-programming methodology is used here where we use input and output data for Decision Making Units (DMU). In our study, we have taken 28 firms within the entire industry and industry is divided into 3 broad sub sectors comprising of all the firms under our consideration, each firm is considered as Decision Making Unit (DMU). The DEA methodology was initiated by Charnes et al. (1978) who built on the frontier concept started by Farell (1957). The methodology used in this paper is based on the work of Fare et al., 1994 and Coelli et al., 1998. We have used the DEA- Malmquist Index to calculate the total factor productivity growth in Indian paper industry which measures changes in total output relative to input. This idea was developed by a Swedish statistician Malmquist (1953). It is a suitable methodology because of following reasons (Mahadevan, 2001). First, the data envelopment analysis approach is an improvement over translog index approach. In translog approach, technical inefficiency is ignored and it calculates only technical change which is wrongly interpreted as TFP growth. While in the literature of productivity, TFPG is composed of technical change and technical efficiency. Second, DEA also identifies the sources of TFP growth which will help the policy makers to identify the specific source of low TFP growth. Another advantage of nonparametric nature of DEA is that it reveal best practice frontier rather a central tendency properties of frontier. In DEA, there is also no need to estimate any production function. It only requires data input and output quantities, and no price data is needed to determine appropriate weights as is necessary with either econometric or index number approaches (Lambert and Parker, 1998). This Malmquist productivity index can be decomposed into efficiency change, technical change and total factor productivity growth. TFPG is geometric mean of efficiency change and technical change. Fare et al. (1994) suggests that if suitable panel data are available, the required distance measures of Malmquist Total Factor Productivity Index can be calculated using DEA. They have defined the output based MTFPI as a geometric mean of two indices. Contrary to Fare et al. (1994), who considered an input based Malmquist index, we use an output based Malmquist index in the current paper.

Non-parametric Data Envelopment Analysis (DEA) and parametric Stochastic Frontier Analysis (SFA) have become very popular in the analysis of productive efficiency. There are multiple techniques to calculate or estimate the shape of the efficiency frontier. Most investigations aimed at measuring efficiency are based either on parametric or nonparametric methods. The main difference between the parametric and the non-parametric approach is that parametric frontier functions require the *ex-ante* definition of the functional form of the efficiency frontier. The non-parametric approach constructs an efficiency frontier using input/output data for the whole sample following a mathematical programming method. This frontier provides a benchmark by which the efficiency performance can be judged. This technique is therefore primary data-driven. The advantage of this approach is its transparency and its facility to handle multiple outputs. Moreover, this approach does not require assumptions about the specific functional form of the production function, i.e. no data on input and output prices are required, since the frontier relies on the input and output data only. The main disadvantage of this approach is its deterministic nature. Results tend to depend heavily on the composition and size of the sample as well as the selection of input and output variables used. Moreover, non-parametric methods tend to be sensitive to measurement errors, statistical noise and outliers.

A very common parametric approach is the Stochastic Frontier Analysis (SFA). It is a statistical method to fit the frontier. It is based on econometric methods. This approach assumes a specific functional form for the relationship between input and output. The advantage of this method is that it is able to cover the effects of exogenous shocks, i.e. nondiscretionary factors. The model can specify the equations based on such assumptions.

The main difference between the various methods of estimation is based upon the approach chosen for the decomposition of the residual between the random disturbance and the efficiency term. Stochastic Frontier Approaches (SFA) relies on distributional assumptions for both components of the residual to disentangle them, while DFA is based on more intuitive assumptions allowed by the use of panel data. DEA simply assumes that the residual represents the whole inefficiency term, which can overestimate the inefficiencies. Moreover, parametric approaches specify a functional form for the efficiency frontier, while nonparametric approaches do not need this assumption. This can be viewed as a disadvantage of the parametric approaches, as the functional form may not fit to data.

A parametric approach uses econometric techniques and imposes a *priori* the functional form for the frontier and the distribution of efficiency. A non-parametric approach, on the contrary, relies on linear programming to obtain a benchmark of optimal constant production-factor combinations. The most popular methods are Stochastic Frontier Analysis (SFA), which is stochastic and parametric, and Data Envelopment Analysis (DEA), which is deterministic and non-parametric.

Malmquist TFP Index and decomposing components:

In this study, the Malmquist (output-based) productivity index (MPI) has been used to measure the productivity change and to decompose this productivity change into the technical change index (TECHCH) and the technical efficiency change index (EFFCH). Technical efficiency changes was further decomposed into pure technical efficiency (PEEFCH) and scale efficiency (SCH) components using the Data Envelopment Analysis (DEA) framework of Färe et al. (1994).

We start by considering firms which use *n* inputs to produce *m* output. Denote $x \in R_+^n$ and $y \in R_+^m$ as, respectively, the input vector and output vector of those firms. The set of production possibilities of a firm at time *t* can be written as:

$$S^t = \{(x^t, y^t) \mid x^t \text{ can produce } y^t\} \tag{1}$$

Fare, Grosskopf, Norris & Zhang (1994) followed Shephard (1970) to define the output distance function at time t as:

$$D_0^t(x^t, y^t) = \inf\{\theta \mid (x^t, y^t / \theta) \in S^t\} = (\sup\{\theta \mid (x^t, \theta\, y^t) \in S^t\})^{-1} \tag{2}$$

The subscript *o* is used to denote the output-based distance function. Note that, $D_0^{\,t}(x^t, y^t) \le 1$, if and only if $(x^t, y^t) \in S^t$, and $D_0^{\,t}(x^t, y^t) = 1$, if and only if (x^t, y^t) is on the frontier of the technology. In the later case, Farrell (1957) argued that the firm is technically efficient.

To define the Malmquist index, Fare et al. (1994) defined distance functions with respect to two different time periods:

$$D_0^{\,t}(x^{t+1}, y^{t+1}) = \inf\{\theta \mid (x^{t+1}, y^{t+1}/\theta) \in S^t\} \tag{3}$$

and

$$D_0^{\,t+1}(x^t, y^t) = \inf\{\theta \mid (x^t, y^t/\theta) \in S^{t+1}\} \tag{4}$$

The distance function in (3) measures the maximal proportional change in output required to make (x^{t+1}, y^{t+1}) feasible in relation to technology at time t. Similarly, the distance function in (4) measures the maximal proportional change in output required to make (x^t, y^t) feasible in relation to technology at time *t + 1*. The output-based Malmquist TFP productivity index can then be expressed as:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \left[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \tag{5}$$

The term outside the brackets shows the change in technical efficiency while the geometric mean of the two ratios inside the brackets measures the shift in technology between the two periods *t* and *t + 1;* this could be called technological progress. So:

$$\text{Efficiency change} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \tag{6}$$

$$\text{Technical change} = \left[\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \tag{7}$$

In each of the formulae above, a value greater than one indicates a positive growth of TFP (an improvement) from a period t to t+1 and a value smaller than one represents deteriorations in performance over time.

We can decompose the total factor productivity growth in following way as well.

MTFPI = Technical Efficiency Change X Technical change
(Catching up effect) (Frontier Effect)

MTFPI is the product of measure of efficiency change (catching up effect) at current period *t* and previous period *s* (average geometrically) and a technical change (frontier effect) as measured by shift in a frontier over the same period. The catching up effect measures that a firm is how much close to the frontier by capturing extent of diffusion of technology or knowledge of technology use. On the other side, frontier effect measures the movement of frontier between two periods with regards to rate of technology adoption. DEA-Malmquist TFP Index does not assume that all the firms or sectors are efficient; therefore any firm or sector can be performing less than the efficient frontier. In this methodology, we will use the output oriented analysis because most of the firms and sectors have their objective to maximize output in the form of revenue or profit. It is also assumed that there is constant return to scale (CRS) technology to estimate distance functions for calculating Malmquist TFP index and if technology exhibits constant return to scale ,the input based and output based Malmquist TFP Index will provide the same measure of productivity change.

5. Empirical Results of Malmquist TFP growth

The discussion will be divided into two sub-sections. In the first section, we will generally look into the descriptive analysis of the variables. The main target is to understand the behaviour of the variables itself, by looking at the distribution of mean, median, maximum, minimum, standard deviation, skewness, kurtosis and the Jarque-Bera test value of each variable. The next subsection will be focusing on the estimation results of productivity growth.

The mean, median, maximum, standard deviation, skewness, kurtosis and Jarque-Bera value can determine the statistical behaviour of the variables. The descriptive statistics of the variables of the model are summarized in the Table 1 below. The relatively bigger figure of standard deviation indicates that the data dispersion in the series is quite large. This finding suggests that almost all the firms within paper industry included in the sample were having large dispersion level of output, material, labour and capital across time series.

Data shows negative skewness for material and positive skewness for capital, labour and output. All the variables have positive kurtosis indicating leptokurtic distribution. Positive kurtosis would indicate a peaked distribution, which is said to be leptokurtic. That means flatter tails than the normal distribution. In terms of shape, a leptokurtic distribution has a more acute peak around the mean and fatter tails. The Jarque-Bera test, a type of Lagrange multiplier test, was developed to test normality, heteroscedasticy, and serial correlation (autocorrelation) of regression residuals. The Jarque-Bera statistic is computed from skewness and kurtosis and asymptotically follows the chi-squared distribution with two degrees of freedom.

Table 1: Descriptive statistics

Statistical measures/ Variables	Capital	Labour	Material	Output
Mean	5859.800	152552.3	1136.560	2592.880
Median	4782.000	146650.0	1300.000	2507.000
Maximum	10321.00	185461.0	1693.000	4459.000
Minimum	2072.000	125153.0	600.0000	1112.000
Std. Dev.	2933.390	20134.50	364.4422	1156.615
Skewness	0.360203	0.195586	-0.135537	0.168130
Kurtosis	1.553683	1.505112	1.539930	1.579510
Jarque-Bera	2.719603	2.487195	2.297173	2.219648
Probability	0.256712	0.288345	0.317085	0.329617
Observations	28	28	28	28

Source: Author's own estimate

Jarque-Bera test statistics is used for testing whether the data series is normally distributed. The high probability value estimated above accepts null hypothesis that the data series is normally distributed. The outcome were supported by the small figure of JB test (Jarque-Bera probability test), where the null hypothesis (that the data are normally distributed) can not be rejected. While testing for normality, it was found that Jarque-Bera statistics with p values 0.256712 for capital, 0.288345 for labour, 0.317085 for material, 0.329617 for output (all are greater than 0.05) implies that variables under our consideration are normally distributed.

In this section, we have calculated total factor productivity growth and its components using Malmquist Productivity Index under three inputs- material, labour and capital and one output framework. We have estimated the Malmquist productivity index and its two components for 3 Indian paper and paper products industry over the pre (1979-80 to 1991-92) and post (1991-92 to 2006-07) liberalization periods. Coelli's (1996) computer program, DEAP 2.1, which adopts the non-parametric linear programming techniques of Fare et al., (1994), was employed in the estimation of the Malmquist productivity index and its two components. Estimates of MTFPI of Indian paper Industry at aggregate level are presented in Table 2.

Table 2: Malmquist Index Summary of Annual Means

YEAR	EFFCH	TECHCH	MTFPCH	YEAR	EFFCH	TECHCH	MTFPCH
1979-80	-	-	-	1991-92	1.001	0.944	0.945
80-81	0.998	0.949	0.947	92-93	1.001	0.971	0.972
81-82	0.995	1.107	1.101	93-94	0.971	0.906	0.880
82-83	1.006	0.977	0.983	94-95	1.032	0.933	0.963
83-84	1.000	0.989	0.989	95-96	1.000	0.948	0.948
84-85	0.975	0.902	0.879	96-97	0.999	0.921	0.920
85-86	1.014	0.990	1.004	97-98	1.001	1.607	1.609
86-87	1.003	0.983	0.986	98-99	0.995	0.860	0.856
87-88	1.009	0.937	0.945	99-'00	0.982	0.936	0.920
88-89	1.000	1.849	1.848	00-01	1.002	0.849	0.851
89-90	1.000	0.867	0.868	01-02	1.001	1.288	1.289
90-91	0.996	0.987	0.983	02-03	0.952	0.803	0.765
91-92	1.001	0.944	0.945	03-04	1.038	0.853	0.886
				04-05	1.017	1.063	1.081
				05-06	1.014	0.948	0.962
				06-07	1.000	0.913	0.913
Mean	0.9997	1.052	1.0549	Mean	1.00097	0.9642	0.967

Source: Author's own estimate by *DEAP, version 2.1.*

We have calculated Malmquist total factor productivity and efficiency change, technical change for all the years in the sample. A summary description of the average performance of sub sectors within the paper industry over the entire period is presented in Table 3.

Table 3: Malmquist Index Summary of Firm Means (:1979-80 to 2006-07)

Sub sector	EFFCH	TECHCH	MTFPCH
1. Manufacture of Pulp, Paper and Board including Manufacture of Newsprint.	1.000	0.930	0.930
2. Manufacture of Containers and Boxes of Paper and Paper Board	1.000	0.992	0.992
3. Manufacture of Paper and Paper Board Articles and Pulp Products + Manufacture of Special Purpose Whether (or) not Printed etc.	1.000	1.057	1.057
Mean	1.000	0.992	0.992

Note: all Malmquist index averages are geometric means.
Source: Author's own estimate.

In Table 3, it has been noticed that paper industry experienced an overall negative TFP growth of 0.8% during 1979-80 to 2006-07. The overall TFP growth is negative due to decline in technical change of 0.8%. This result reveals that decline in the industry's TFPG is due to their productivity based frontier capability. On the other side, it can be said that since the technical change is less than unity, it has a negative effect on the overall TFP growth. The overall technical change in the industry is less than 1 which is a main cause in dampening the total factor productivity for paper sector. Technical efficiency change is the result of pure technical efficiency change and scale efficiency change. With regards to pure efficiency change, it is one or more than one in most of years (not shown in the table). In case of Scale efficiency change, value close to unity shows that in most of the years, industry is operating at optimum scale. Therefore, both Scale efficiency and pure technical efficiency have contributed to the improvement in Technical efficiency.

Lower productivity growth rate reflects a lower growth rate in the output and higher or moderate growth rates in the uses of all three inputs. The decomposition of the MTPI provides guiding principle for an explanation for the measured productivity growth. Technical efficiency change can make use of existing inputs to produce more of same product. As one gets more experience in producing some product, it becomes more and more efficient in it. Labour finds new ways to produce by making minor modifications in the process of manufacturing which contribute to higher productivity. The second important source of total factor productivity growth is the change in the technology. Squires and Reid (2004) articulated that technological change is the development of new technologies or new products to improve and shift production frontier upward.

On average, the technical change (TECHCH) also decreased 0.80% while the efficiency change index (EFFCH) seemed to be remaining the same. This reflects that the declining total factor productivity in paper sector's production caused from the non-upgration in innovation of technology rather than the improvements in technical efficiency. Moreover, the results of decomposition suggests that the nearly stability in pure efficiency and in scale efficiency resulted in the stability in efficiency change. As for the zero efficiency change, there seems to be reason for this that some of the firms within the paper sector, still had the problem of excessive labor utilization in producing output and hence, suffered from slight scale inefficiency (decreasing return to scale).

Table 4: Growth rate of Malmquist productivity, technical change and technical efficiency change

Sub sector	Pre-reform period (1980 -81 to 1991 – 92)			Post- reform period (1991 –92 to 2006 –07)			Entire period (1980-81 to 2006 – 07)		
	EFFCH	TECHCH	MTFPCH	EFFCH	TECHCH	MTFPCH	EFFCH	TECHCH	MTFPCH
1. Manufacture of Pulp, Paper and Board including Manufacture of Newsprint.	-0.03	-5.94	-5.88	0.081	-6.51	-6.22	0.000	-7.0	-7.0
2. Manufacture of Containers and Boxes of Paper and Paper Board	0.0083	9.44	10.2	0.11	-4.61	-4.37	0.000	-0.8	-0.8
3. Manufacture of Paper and Paper Board Articles and Pulp Products + Manufacture of Special Purpose Whether (or) not Printed etc.	0.0092	12.14	12.14	0.10	0.39	0.69	0.000	5.7	5.7
Mean	-0.0042	5.21	5.49	0.097	-3.58	-3.3	0.000	-0.8	-0.8
Trend growth rate of MTFP for the entire period									-0.11

*Trend growth rate for the entire period is obtained from semi log function. log Y = a + bt, where Y = TFP index, a = Constant, t = Time in years, b = Regression coefficient.

Source: Author's own estimate.

Table 4 above shows that total factor productivity growth during pre-reform period shows positive TFP growth rate which is posted as at 5.49% and in post-liberalization period, it further declined to -3.3%. Table 4 displays the average growth rates of EFFCH, TECHCH and TFP in each sub-sector of Indian paper and paper products industry. Table 4 illustrates that the growth rate of TFP is abruptly declining in the post-reform period (-3.3 %) than in the pre-reform period (5.49%). Two sub-sectors (1&2) evidenced negative TFP growth in the post-reform period, whereas one sub-sector (1) had negative TFP growth in the pre-reform period. Only sub sector 3 evidenced positive but declining TFP growth in both periods. In the post-reform period, TECH decreases in negative fashion and EFFCH slightly increases. As a result, since there was decrease in TECH, it results in a modest decrease in TFP. After economic reform, in all sub sectors, slight efficiency improvement is noticed. But, sub-sector 1 and 2 displays technical regress during post-reforms period.

Total factor productivity growth has been estimated by various studies .Those studies report positive or negative trend in TFP growth depending on the time period selected and time period considered.

Table 5: Comparison of our estimate with that of Sathaye

Period	Own estimate	Sathaye
Entire Pre-reform period (1979-80 to 1991-92)	5.49	9.5(1982- ‘90)
Entire Post-reform period (1991-92 to 2003-04)	-3.3	-13.3(1990- ‘93)
Entire period (1979-80 to03-04)	-0.80	-2.2(1973- ‘93)

Our study of TFPG of Indian paper industry is compared with the study of Sathaye (Table 5) where both estimates show similar trend in sign condition (either positive or negative) during pre-liberalization, post-liberalization and entire period. Sathaye’s estimate displays high positive growth rate in TFP during pre liberalization period (9.5%) but dismal declining negative growth rate in TFP during post liberalization (-13.3%) and entire time frame (-2.2%) although sub-periods demarcated as pre and post-reform periods in two studies are not consistently uniform. But our estimated result shows that in all the three demarcated period-pre liberalization, post liberalization and entire period, growth rate in TFP (either positive or negative) are lesser as compared to Sathaye.

Moreover, for regressing time(t) on productivity indices (TFP) to capture effect of period changes on productivity growth, we use the equation as follows:

TFP= a + bt where TFP is the malmquist productivity index, t is time.

The result of the regression is as follows:

$$\underset{}{TFP=1.0458 - \underset{(-0.432)}{0.0025t}}$$

The result shows that period change does not have any noticeable significant impact on productivity growth.

6. Trend in Total Factor Productivity Growth with Adjustment for Capacity Utilization

Economic activity fluctuates over the business cycle, periods of high demand alternates with downturns in demand. Capital stocks are hard to adjust rapidly, so periods of low demand are typically periods of low capital utilization. A residual calculated using capital stock data thus fluctuates procyclically along with the rate of utilization. These fluctuations tend to obscure the movements in the longer run components of the residual and make it hard to distinguish significant break in trends .Productivity measures can be biased if variations in capacity utilizations are not taken into accounts (Jorgenson, 1967; Morrison, 1985). It has long been recognized that the existence of temporary equilibrium which is connected with the business cycle, can bias measured productivity growth away from its long run path. Earlier researchers have attempted to a variety of cyclical adjustments in order to take account of variations in the utilizations of stocks of factors of production. Some, like Norsworthy, Harper and Kunze (1978), select time intervals for which the capacity utilization is widely believed to be nearly one which is called the 'peak to peak' adjustment method. Jorgenson and Grileches (1967) adjust for the variation in capital utilization using the relationship between electricity consumption and the horse power rating of electric motors. Denison (1979) in a number of studies uses variations in capital's share of income. These adjustment procedures have been controversial primarily because they have appeared to be *ad hoc* as well as not theoretically motivated. Unfortunately, the process that generates the data is unknown and it is difficult to assess the validity of such adjustments.

Therefore, an adjustment to productivity measure is of vital importance in order to capture the effect of variation in capacity utilization on TFPG. This section estimates how TFPG measure may be changed with the variation in capacity utilization .We regress the log difference of the measured productivity growth on the log difference of the capacity utilization rate which is a proxy for business cycle. Subsequently, we have adjusted the average of the regression error term so that it equals the original productivity measure when the productivity measure is adjusted for cyclical factors.

$$\Delta \text{ Log TFP}_t = a + b\Delta \text{ Log CU}_t$$

$$\underset{}{\Delta \text{ LogTFP}} = -0.0015 - \underset{(-2.39)}{0.0998}\Delta \text{ Log CU}_t$$

Where CU is economic capacity utilization (derived from optimization procedure as shown in Appendix: A-3) and t statistics are given in the parenthesis. $R^2 = 0.505$

Our regression result shows that effect of CU on measured productivity growth is significant at 0.05 level.

Rate of changes in CU are found to be positively correlated with TFP growth rate. This implies that among many other factors like growth in output, import of capital goods, advanced technology, trade policy etc. that affect TFPG, CU may have a resultant positive effect on TFPG rate. With the adjustment of capacity utilization, positive growth rate of TFP (5.49%) in 80's becomes smaller and sharper and displays a noticeable deceleration in growth rate in TFP (-0.159%) in 90's, and CU adjusted TFPG sharply declined during the entire time frame on an average (-0.061).

Table 6: Growth rate after adjusting capacity utilization, 1980 -81 to 2006- 07

Time interval	TFP growth rate (% per annum).					
	Unadjusted values			Values adjusted for capacity utilization		
	EFFCH	TECHCH	MTFPCH	EFFCH	TECHCH	MTFPCH
Pre-reform period i.e. 1980 -81 to 1991 – 92	-0.0042	5.21	5.49	-0.010	-0.148	-0.159
Post- reform period i.e. 1991 –92 to 2006 –07	0.097	-3.58	-3.3	0.009	-0.027	-0.019
Entire period i.e. 1980-81 to 2006 – 07	0.000	-0.8	-0.8	0.003	-0.062	-0.061

 # Growth rates for the entire periods are obtained from the semi- log trend.
Source: Own estimate.

On the contrary, it is found from the comparison between pre and post- reform period that difference in average annual growth rate between pre-reform (1980-81 to 1991-92) and post-reform period (1991-92 to 2003-2004) becomes smaller after incorporating effect of CU into TFP growth calculation; while unadjusted Malmquist measure implies a slowdown of -8.79% (-3.3% minus 5.49%), capacity adjusted TFPG measure suggest comparatively smaller improvement of 0.14% (-0.019% minus -0.159%) following trade reform. In a nut shell, inspection of entries in table 6 reveals that removal of cyclical effect from the estimated TFP growth does not affect its overall movement but remarkably mitigates its variation because variations between sub-periods are smaller after adjusting capacity utilization as cyclical factors.

7. Conclusion

The estimates of productivity changes in the Indian paper and paper products industry during the period 1979-80 to 2006-07 disclose despairing results at the aggregate and sub-sectoral levels. The average TFP growth rate of Indian paper industry at aggregate level was 5.49% in the pre-reform period, but it was -3.3% in the post-reform period. This result suggests that economic reforms have adverse impact on paper sector's productivity growth resulting declining TFP growth rate. This declining trend is prevailing also to all the sub-sectors of the industry. Productivity growth during the pre-reform period was attributed to technical change both at the aggregate and sectoral level. During the post-reform period, Indian paper and paper products industry as whole witnessed a decline in the productivity change largely due to the greater drop in the technical change although efficiency slightly improved. The declining growth in technical change and failure to adopt it efficiently along with nearly constant technical efficiency change has contributed to the decreased productivity growth of Indian paper and paper products industry. Moreover, removal of short run variations in capacity utilization from the estimated TFP growth hardly affects its overall movement but remarkably mitigates its variation because variations between sub-periods are lesser after adjusting capacity utilization as cyclical factors.

However, there are some weaknesses associated with a non-parametric approach. First, since a non parametric method is deterministic and attributes all the variation from the frontier to inefficiency, a frontier estimated by it is likely to be sensitive to measurement errors or other noise in the data. In other word, it does not deal with stochastic noise. Another noise of non para- metric method is that it does not permit statistical test and hypotheses to pertain to production structure and the degree of inefficiency. In this paper, a nonparametric approach is used because it is less data demanding i.e it works quite well with a small sample size, compared to a parametric approach. Thus, the small sample size of 3 subsectors comprising of 28 firms, is conducive to the use of a nonparametric approach.

In conclusion, it can be emphasized that there is an urgent need for the implementation of specific policies to improve technical progress as well as efficiency change in order to enhance long-run TFP growth. Sectors and firms within the industry should be encouraged to use existing technology more effectively through enhanced expertise and training.

References

Ahluwalia, I.J., 1991, *Productivity and growth in Indian manufacturing*, Oxford University Press, Delhi.

Balakrishnan, P. and Pushpangadan, K., 1994, 'Total factor productivity growth in manufacturing industry: A fresh look', *Economic and political weekly,* July, 30.

Balakrishnan, P., Pushpangadan, K. and Suresh Babu, M., 2000, 'Trade liberalization and productivity growth in manufacturing: Evidence from firm level panel data', *Economic and political weekly,* October 7, pp. 3679-82.

Brahmananda, P.R., 1982, *Productivity in the Indian economy: Rising inputs for falling outputs*, Himalaya Publishing House, Delhi.

Coelli, T.J., 1996, 'Measurement of Total Factor Productivity and Biases in Technological Change in Western Australian Agriculture', *Journal of Applied Econometrics,* 11, pp. 77-91.

Coelli, T., Rao, D.S.P. and Battase, G.E., 1998, *An Introduction to Efficiency and Productivity Analysis*, *Boston, Kluwer Academic Publishers*.

Charnes, A., Cooper, W.W. and Rhodes, E., 1978, 'Measuring the Efficiency of Decision Making Units', *European Journal of Operations Research,* 2, pp. 429-444.

Chand, S. and Sen, K., 2002, 'Trade liberalization and productivity growth: An evidence from Indian manufacturing', *The Review of Development Economics*, 6, 1, pp. 120-132.

Datt, R., Sundharam, K.P.M., 1998, *Indian Economy,* Chand & Company Ltd., New Delhi.

Das, D., 1999, *Productivity growth in Indian manufacturing: An application of Domer Aggregation* presented at the workshop on measurement of productivity in India, Institute of Human Development, New Delhi, July, pp. 9-10.

Denison, E.F., 1979, *Accounting for slower economic growth: The United States in the 1970s* (The Brooking Institution , Washington, DC).

Farrell, M.J., 1957, 'The Measurement of Productive Efficiency', *Journal of the Royal Statistical Society*, 120, pp. 253-81.

Färe, R., Grosskopf, S., Norris, M. and Zhang, Z., 1994, 'Productivity growth, technical progress, and efficiency changes in industrialized countries', *American Economic Review*, 84, pp. 66-83.

Goldar, B.N., 1986, *Productivity growth in Indian industry*, Allied Publishers, New Delhi.

Goldar, B.N. and Anita K., 2003, 'Import liberalization and productivity growth in Indian manufacturing industries in the 1990's', *The Developing Economies*, 41, pp. 436-59.

Goldar, B.N., 2004, Indian manufacturing: Productivity trends in pre and post reforms periods, *Economic and Political Weekly,* November 20.

Jorgenson, D. W. and Zvi G., 1967, 'The explanation of productivity change', *Review of Economic Studies*, 34, pp. 249-282.

Jorgenson, D.W, 1988, 'Productivity and Post war US economic growth', *Journal of Economic Perspectives,* 2, 4, pp. 23-41.

Krishna and Mitra, D., 1998, 'Trade liberalization, market discipline and productivity growth: New evidence from India', *Journal of Development Economics*, 56, pp. 55-83.

Lambert, D.K. and Parker, E., 1998, 'Productivity in Chinese provincial agriculture', *Journal of Agricultural Economics,* 49, 3, pp. 378-92.

Mahadevan, R., 2001, 'Assessing the Output and Productivity Growth of Malaysia's Manufacturing Sector', *Journal of Asian Economics*, 12, 4, pp. 587-597.

Malmquist, S., 1953, 'Index Numbers and Indifference Curves', *Trabajos de Estatistica*, 4, 1, pp. 209-42.

Madheswaran, S., Hailin L. and Badri N. R., 2007, 'Productivity Growth of Indian manufacturing Sector: Panel Estimation of Stochastic Production frontier and Technical Inefficiency', *The Journal of Developing Area*, 40, 2, pp. 35-50.

Majumdar, S. K., 1996, 'Fall and rise of productivity in Indian industries: Has economic liberalization had an impact?', *Economic and political weekly*, November 30, pp. M 46-M 53.

Morrison, C.J,, 1985, 'On the Economic Interpretation and measurement of optimal capacity', *Review of Economic studies LII*, pp. 295-310.

Meadows, D. G., 1997, 'The Pulp and Paper Industry in India', *TAPPI Journal*, 80, 8, August 1997, pp. 91-96.

Murty, M.N., 1986, 'Interfuel Substitution and Derived Demands for Inputs in the manufacturing sector of India', *Journal of Quantitative Economics,* 2, 1, pp. 119-135.

Norsworthy, J. R., Harper, M. J. and Kent K., 1979, 'The slowdown in productivity growth: Analysis of some contributing factors', *Brooking papers on Economic Activity*, Fall, pp. 387-427.

Pattnayak, S.S. and Thangavelu, S.M., 2005, 'Economic Reform and Productivity Growth in Indian Manufacturing Industries: an interaction of Technical Change and Scale Economies', *Economic Modelling*, 22, pp. 601-615.

Pradhan, G. and Barik, K., 1999, Total factor productivity growth in developing economies- A study of selected industries in India, *Economic and political weekly*, August, 6.

Ray, S. and Pal, M.K., 2008, 'On the measurement of capacity utilization: An evidence from Indian chemical Industry', *Arthavijnana,* L, 2, June 2008.

Rao, M., 1996, Manufacturing productivity growth: Method and measurement, *Economic and Political Weekly*, November, 2, pp. 2927-36.

Rodrick, D. and Subramanian, A., 2004, 'From Hindu growth to productivity surge: The mystery of the Indian growth transition', NBER Working paper, no W10376.

Sharma, V.K., Ramaswamy, K.V., Vaidya, R.R., Hadker, N. and Beukering, P.V., 1998, 'The Indian Paper Industry', in: Beukering, Pieter van, Vinod K. Sharma (ed.), 1998: *Wastepaper Trade and Recycling in India*, Jodhpur, India: Scientific Publishers.

Sindhu, J. and Balasubramanyam V.N., 2006, 'India's Growth Performance: The Enigmatic Decade of the Eighties', *The Indian Economic Journal*, 54, 3, pp. 7-24.

Singh, S., Colli, T. and Fleming, E., 2000, The effect of private sector competition upon productivity growth in Indian Diary Processing Plants, Centre for efficiency and policy analysis, Working paper no.1/2000, University of New England.

Sharma, K., 1999, 'Productivity growth in Developing countries: An international comparison', *The current State of Economic Science,* 3.

Shephard, R. W., 1970, *Theory of cost and production functions*, Princeton University Press, Princeton, NJ.

Squires, D., D. and Hester R. K., 2004, 'Using Technical Innovation in Chemical Practice: The Drinkers', Check up Software Programme', *Journal of chemical psychology*, 60, 2, pp. 159-69.

Srivastava, V., 2001, The impact of India's economic reforms on Industrial productivity, efficiency and competitiveness: A panel study of Indian companies, NCAER, New Delhi.

Schumacher, K. and Sathaye, J., 1999, India's Pulp and Paper Industry: Productivity and Energy Efficiency, LBNL 41843, July, Energy Analysis Programme,Environmental Energy Technology Division, Lawrence Berkeley, CA.

Tata Service Limited (TSL), 2003, Reforms and Productivity trends in Indian manufacturing sectors, Department of Economics and Statistics, Tata Service Limited, Mumbai.

Topalova, P., 2004, Trade liberalization and firm productivity: The case of India, IMF working paper WP/04/28, Asia Pacific Department, February.

Unel, B, 2003, Productivity trends in Indian manufacturing sectors in the last two Decades, IMF working paper no. WP/03/22.

Appendix

A1 Energy Inputs: Industry level time series data on cost of fuel of Indian Paper sector have been deflated by suitable deflator (base 1981-82 = 100) to get real energy inputs. An input output table provides the purchase made by manufacturing industry from input output sectors. These transactions are used as the basis to construct weight and then weighted average of price index of different sectors is taken. Taking into consideration 115 sector input -output table (98-99) prepared by CSO, the energy deflator is formed as a weighted average of price indices for various input-output sectors which considers the expenses incurred by manufacturing industries on coal, petroleum products and electricity as given in I-O table for 1998-99. The WIP indices (based 1981- 82) of Coal, Petroleum and Electricity have been used for these three categories of energy inputs. The columns in the absorption matrix for 66 sectors belonging to manufacturing (33- 98) have been added together and the sum so obtained is the price of energy made by the manufacturing industries from various sectors. The column for the relevant sector in the absorption matrix provides the weights used.

A2 Capital Stock: The procedure for the arriving at capital stock series is depicted as follows:

First, an implicit deflator for capital stock is formed on NFCS at current and constant prices given in NAS. The base is shifted to 1981-82 to be consistent with the price of inputs and output.

Second, an estimate of net fixed capital stock (NFCS) for the registered manufacturing sector for 1970-71 (benchmark) is taken from National Accounts Statistics. It is multiplied by a gross-net factor to get an estimate of gross fixed capital stock (GFCS) for the year 1970-71. The rate of gross to net fixed asset available from RBI bulletin was 1.86 in 1970-71 for medium and large public Ltd. companies. Therefore, the NFCS for the registered manufacturing for the benchmark year (1970-71) as reported in NAS is multiplied by 1.86 to get an estimate of GFCS which is deflated by implicit deflator at 1981-82 price to get it in real figure. In order to obtain benchmark estimate of gross real fixed capital stock made for registered manufacturing, it is distributed among various two digit industries (in our study, paper industry) in proportion of its fixed capital stock reported in ASI, 1970-71)

Third, from ASI data, gross investment in fixed capital in Indian paper industry is computed for each year by subtracting the book value of fixed in previous year from that in the current year and adding to that figure the reported depreciation on fixed asset in current year. (Symbolically, $I_t = (\beta_t - \beta_{t-1} + D_t) / Pt$) and subsequently it id deflated by the implicit deflator to get real gross investment.

Fourth, the post benchmark real gross fixed capital stock is arrived at by the following procedure. Real gross fixed capital stock (t) = real gross fixed capital stock (t – 1) + real gross investment (t). The annual rate of discarding of capital stock (D_{st}) is assumed to be zero due to difficulty in obtaining data regarding D_{st}.

A3 Econometric Model in estimating capacity utilization and data description: Considering a single output and three input framework (K, L, E) in estimating CU, we assume that firms produce output within the technological constraint of a well-behaved production function.

$Y = f(K, L, E)$ where K, L and E are capital, labour and energy respectively. Since capacity output is a short-run notion, the basic concept behind it is that firm faces short-run constraints like stock of capital. Firms operate at full capacity where their existing capital stock is at long-run optimal level. Capacity output is that level of output which would make existing short-run capital stock optimal.

Rate of CU is given as

$$CU = Y/Y^* \tag{1}$$

Y is actual output and Y* is capacity output.

In association with variable profit function, there exist a variable -cost function which can be expressed as

$$VC = f(P_L, P_E, K, Y) \tag{2}$$

Short run total cost function is expressed as

$$STC = f(P_L, P_E, K, Y) + P_K . K \tag{3}$$

P_K is the rental price of Capital.

Variable cost equation which is variant of general quadratic form for (2) that provide a closed form expression for Y* is specified as

$$\begin{aligned} VC = \alpha_0 + K_{-1} (\alpha_K + ½ \beta_{KK} \left[\frac{K_{-1}}{Y}\right] + \beta_{KL.} P_L + \beta_{KE.} P_E) \\ + P_L (\alpha_L + ½\beta_{LL.} P_L + \beta_{LE.} P_E + \beta_{LY.} Y) \\ + P_E (\alpha_E + ½\beta_{EE.} P_E + \beta_{EY.} Y) + Y(\alpha_Y + ½ \beta_{YY.} Y) \end{aligned} \tag{4}$$

K_{-1} is the capital stock at the beginning of the year which implies that a firm makes output decisions constrained by the capital stock at the beginning of the year.

Capacity output (Y*) for a given level of quasi-fixed factor is defined as that level of output which minimizes STC. So, the optimal capacity output level, for a given level of quasi-fixed factors, is defined as that level of output which minimizes STC. So, at the optimal capacity output level, the envelop theorem implies that the following relation must exist.

$$\partial STC/\partial K = \partial VC/\partial K + P_K = 0 \tag{5}$$

In estimating Y*, we differentiate VC equation (4) w.r.t K_{-1} and substitute expression in equation (5)

$$Y^* = \frac{-\beta_{KK.} K_{-1}}{(\alpha_{K} + \beta_{KL} P_L + \beta_{KE} P_E + P_K)} \tag{6}$$

The estimates of CU can be obtained by combining equation (6) and (1).

Output is measured as real value added produced by manufacturers ($Y = P_L L + P_K.K_{-1} + P_E.E$) suitably deflated by WIP index for manufactured product (base 1981 – 82 = 100) to offset the influence of price changes. In CU measurement, variable cost is sum of the expenditure on variable inputs ($VC = P_L L + P_E.E$).Total number of persons engaged in glass sector are used as a measure of labour inputs. Price of labour (P_L) is the total emolument divided by number of labourers which includes both production and non-production workers. Deflated cost of fuel has been taken as measure of energy inputs. Due to unavailability of data regarding periodic price series of energy in India, some approximations become necessary. We have taken weighted aggregative average price index of fuel (considering coal, petroleum and electricity price index, suitably weighted, from statistical abstract) as proxy price of energy. Deflated gross fixed capital stock at 1981-82 prices is taken as the measure of capital input. The estimates are based on perpetual inventory method. Rental price of capital is assumed to be the price of capital (P_K) which can be estimated following Jorgenson and Griliches (1967):

$$P^t_K = r_t + d_t - \frac{P^{\bullet}_k}{P_k}$$

where r_t is the rate of return on capital in year t, d_t is the rate of depreciation of capital in the year t and $\frac{P^{\bullet}_k}{P_k}$ is the rate of appreciation of capital .Rate of return is taken as the rate of interest on long term government bonds and securities which is collected from RBI bulletin (various issues). The rate of depreciation is estimated from the reported figures on depreciation and fixed capital as available in ASI which Murty (1986) had done earlier. However, we have not tried corrections for the appreciation of value of capital in the estimates of price of capital services.