Productivity Growth and Convergence across Firms: A Case Study of India's State Transport Undertakings during 2000s

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Abstract

The motive of this study is to put forward new information concerning the productivity and productive efficiency of the State Road Transport Undertakings (STUs) in India during 2000s. A well-known multilateral index procedure proposed by Caves, Christensen, and Diewert (1982) is used to compute the growth and relative levels of total factor productivity of the STUs. Productive efficiency estimates are then calculated by separating the effects of variations in the variables beyond managerial control from the total factor productivity measures. We also examined the temporal relationship of the cross-sectional rankings of individual STUs' productive efficiency estimates. To address this issue, we calculated Kendall's index of rank concordance along with coefficient of variation of productive efficiency estimates for the sample period. Annual data for a sample of eleven STUs that operated during the period 2000-01 to 2010-11 are used for the purpose of estimation. We find that there is a wide disparity among STUs according to their total factor productivity and productive efficiency levels and growth. Although not very strong, there is a positive relationship between total factor productivity and size of STUs. However, productive efficiency and size of STUs has statistically insignificant relationship, which shows that the productive efficiency of STUs is independent of their size. Comparing productive efficiency with the total factor productivity, it is found that within a firm, productive efficiency has a much larger spread whereas, inter-firm spread is less in case of productive efficiency. Using regression analysis, we found that although the coefficient of variation of productive efficiency estimates is decreasing over time, but decrease is statistically insignificant. According to multi-annual Kendall index, the null hypothesis of no association between productive efficiency ranks is rejected. However, according to binary-Kendall index, the null hypothesis could not be rejected for all the years. In other words, cross-sectional dispersion of STUs' productive efficiency is diminishing over time but not significantly.

Keywords: Productivity, Bus Transport, State Transport Undertakings, India.

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1. Introduction

India's passenger transport for short and medium distances is essentially bus oriented. Buses even compete with railways on certain long-distance routes by offering night services. Buses enjoy a distinct edge over railways for short and medium distances because of their flexibility and accessibility to a large number of cities, towns, and villages. Compared to personalized modes of transport like cars and two-wheelers, buses per passenger-km yield noticeable economy in the use of road space, fuel consumption, vehicular emission, and cost of operation.

Indian bus industry, since independence, has been organized along a mixed pattern of public and private sector ownership. However, industry is dominated by publicly owned State Transport Undertakings (STUs) since private sector is highly fragmented and unorganized. The STUs play an important role in providing passenger transport services, as they are the biggest undertakings in the hands of the respective state governments. Presently, STUs in India are operating with more than a hundred thousand of buses and seven hundred thousand of workers. During the year 2010-11, the total bus-kilometers operated by the STUs were more than fifteen billion, the number of passengers carried was more than twenty five billion, and the volume of operation had crossed the mark of five hundred billion passenger-kilometers.

However, during 2000s, STUs in India faced huge financial losses from their operation. Losses incurred by them increased from around Rs. 20 billion in 2000-01 to Rs. 60 billion in 2010-11. As a result, losses incurred by these undertakings per bus-km of their operation has also increased significantly from Rs. 1.63 in 2000-01 to Rs. 4.22 in 2010-11. Why do STUs in India face such a huge financial losses? Answer of this question requires answer of the following one. What determines financial performance of a firm in general and of a public enterprise in particular? It is easy to show that productivity and prices are the key determinants of profitability of a firm. Productivity, measured as total factor productivity (TFP), of a firm is defined as the ratio of outputs to inputs. Productivity growth, therefore, can arise from an increase in the output that can be produced for a given level of input, or a decrease in input necessary to produce a given amount of output. Therefore, productivity growth has potential to improve the financial performance of a firm through increase in the efficiency of production. However, it is easy to show that productivity and profitability performance would move together in the same direction if and only if input factor prices in comparison to output prices are unchanged. The aim of this study is to find out whether deterioration in STUs' financial performance is because of decline in their productivity or their inability to increase fare in line with the increase in their input factor prices. The study aims not only to analyze productivity and profitability of STUs but also their productive efficiency and its convergence across the firms during 2000s. The analysis is based on a sample of eleven STUs that operated during the period 2000-01 to 2010-11. Sample STUs represent majority of the industry as they produce more than 50% of the output produced by the publicly owned bus transport industry in India.

A well-known multilateral index procedure proposed by Caves, Christensen, and Diewert (1982) is used to compute the growth and relative levels of TFP of the STUs during 2000s. The estimates of TFP are then examined for their association with operating characteristics of the individual STU. Estimates of TFP are also compared with partial factor productivity indicators such as labor productivity (passenger-kilometers per employee), fuel productivity (bus-kilometers per liter of diesel), and bus productivity (bus-kilometers per bus held by the STU). The linkages between TFP, prices, and profitability of STUs are also examined. Residual TFP, a measure of productive efficiency, estimates are then calculated by separating the effects of variations in the variables beyond managerial control from the total factor productivity measures. Finally, we examine whether productive efficiency ranks of the STUs differ significantly across the years. Specifically, we try to examine the temporal relationship of the cross-sectional rankings of individual STUs' productive efficiency estimates. To address this issue, we calculated Kendall's index of rank concordance along with coefficient of variation of residual TFP estimates for the sample period. The motivation for this calculation is to determine whether the STUs that were inefficient are still inefficient or there has been any convergence in their productive efficiency.

This paper is organized into the following sections: Section 2 describes the general concept of productivity and total factor productivity measurement using index number approach for STUs during 2000s. Section 3 deals with the data and its source used for the analysis. Section 4 illustrates the level and growth of TFP, comparison between TFP and indicators of partial factor productivity, and linkages between productivity, prices, and profitability. Section 5 presents the TFP regression results, estimates of residual TFP, and relationship between residual TFP, TFP, and size of STUs. Section 6 elucidates the issue of convergence of residual TFP across the STUs over the sample period. Concluding remarks of the paper are presented in Section 7.

2. Productivity Measurement

The earliest approaches to productivity measurement were based upon ratios of a measure or index of aggregate output divided by the observed quantity of a single input, typically labor. These productivity ratios were usually normalized to some base year, resulting in a productivity index over time, and were used to measure aggregate productivity. This index-number approach based upon the use of single or partial factor productivity measures had the advantage of computational simplicity and feasibility, but is potentially misleading because what passes for a difference in productivity, may in fact merely represent a different use of input mix. For example, the substitution of capital for labor, the introduction of more (labor) efficient vintages of capital, the realization of economies of scale, and the employment of better-trained manpower all show up in the form of increases over time in an index of output per worker.

TFP is the broadest measure of productivity, and the only measure whose increase is unambiguously beneficial, in the sense that, *ceteris paribus*, it corresponds to a decline in the average cost of production. However, labor productivity retains a role in the family of productivity measures relevant to national economic policy. TFP can be measured using non-parametric, semi-parametric, or parametric approaches (refer, Van Biesebroeck, 2007 for strengths and weaknesses of each method). Non-parametric approaches include index number approach and data envelopment analysis whereas parametric approaches are based on econometric analysis where productivity is generally estimated as the time shift in a cost (or production) function. Van Biesebroeck (2007) shows that unless one expects the data to be subject to a lot of measurement errors, index number approach produces consistently accurate productivity growth estimates.[2] TFP measurement and modeling

[2] The index number approach is a "gross" measure of TFP; it does not distinguish between sources of productivity growth. Econometric estimates of TFP are "technological shift" measure; they exclude productivity gains from economies of scale or similar endogenous production characteristics (see, for example, Diewert, 1992).

using index number approach is based on the assumption that inputs are combined so as to minimize the cost of a given output. The more restrictive assumption of profit maximization is not required, nor is the assumption that output is sold in a competitive market. However, it is assumed that inputs are purchased at prices perceived to be constant. For the STUs in India, these assumptions seem to be reasonable. Therefore, this study uses index number approach to estimate the levels and growth of TFP of STUs in India.

TFP indices are the ratio of two separate indices, one for outputs and the second representing total input.[3] Moreover, there is a unique correspondence between the type of index used to aggregate over outputs and inputs and the structure of underlying technology. For example, the Laspeyres indexing procedure, used in many of the earlier productivity studies, has been shown to be exact for, or imply, a linear production function in which all inputs are perfect substitutes in the production process. Similarly, the Tornqvist index, a discrete approximation to the more general Divisia index, implies a homogeneous translog production function. Thus, any given index number implies a particular structure for the underlying production technology.[4]

In its simplest form, TFP is a ratio of output to a weighted sum of inputs. Historically, two common ways of assigning weights for this index are used; either an arithmetic or geometric weighted average of inputs. The arithmetic weighted average, due to Kendrick (1961), uses input prices as the weights; whereas the geometric weighted average of inputs, attributable to Solow (1957), uses input expenditure shares as the weights. As long as the changes in inputs and outputs is not too large, both Kendrick's and Solow's measures of TFP growth arrive at similar results (Nadiri, 1970).

Where multiple outputs exist, TFP is described as a ratio of an index number describing aggregate output levels to an index number describing aggregate input levels. If an index can be derived from some underlying cost, production, revenue, profit, or transformation functions, Diewert (1976) categorizes such an index among those which satisfy "exact" criteria. If that underlying functional form is flexible (i.e., it provides a second order local approximation to an arbitrary functional form), an exact index is termed "superlative". The Tornqvist-Theil quantity index is superlative in the sense that it can be derived from a translog production function. The most popular Tornqvist-Theil index, the discrete Divisia (the index uses information from the previous time period as the reference), is used in time series applications. This index can be computed as follows:

$$\ln TFP_k - \ln TFP_l = \sum_i \left(\frac{R_{ik} + R_{il}}{2} \right) \ln\left(\frac{Y_{ik}}{Y_{il}} \right) - \sum_j \left(\frac{S_{jk} + S_{jl}}{2} \right) \ln\left(\frac{X_{jk}}{X_{jl}} \right) \quad \textbf{(1)}$$

where TFP is total factor productivity index, k and l are adjacent time periods, the Y_{im} are output indices, the X_{jm} are input indices, the R_{im} are output revenue shares, and the

[3] The existence of separate aggregate output and input indices requires that technical change be neutral and that the underlying transformation function be separable in outputs and inputs (Diewert (1976) and Caves *et al.* (1980)). However, Caves *et al.* (1981) point out, violation of these conditions does not necessarily preclude the measurement of TFP growth.

[4] There is linkage of the two approaches to TFP measurement, index number and neoclassical production and cost function, in that the problems of selecting an appropriate production function and a suitable index number can be shown to be dual to each other.

S_{jm} are input cost shares. There are j number of input factors used to produce i number of outputs.[5]

The Divisia "chaining" approach i.e., **(1)** has severe limitations in some applications e.g., with cross-sectional or panel data. There is no obvious way to chain the index and get comparisons between firms since "adjacent" makes little sense in the cross-section. For this study when we allow subscript k and l in **(1)** to represent both firms and time periods, there will be a total of 121 time-differentiated firm observations since we have 11 firms and 11 time periods. The direct use of **(1)** for comparisons of STUs productivity would result in 7260 binary comparisons – the number of possible ways of choosing 2 of the 121 observations to compare. Unfortunately, there is no guarantee of transitivity in such comparisons. For example, in a particular year, firm F_1 might be found to be more productive than firm F_2 and less productive than firm F_3; yet a direct comparison of F_2 and F_3 might indicate that F_3 is less productive than F_2. This lack of transitivity is possible because weights R_{im} and S_{jm} specific to the two firms in question are used. Caves, Christensen and Diewert (1982) address this issue and provide a solution which assumes a hypothetical firm whose sub-component expenditure shares are the arithmetic mean expenditure shares for all firms, and whose sub-component quantities are the geometric means of the sub-component quantities across all firms. This index has clear advantages in dealing with cross-section as well as panel data set. It is transitive (in case of cross-sectional analysis) in similar sense that the Divisia index is transitive (in case of time-series analysis). The hypothetical firm approach provides an unambiguous basis for comparison for observations which have no natural ordering.

Caves, Christensen, and Diewert (1982) proposed the following formula for cross-sectional or panel data set:

$$\ln TFP_k - \ln TFP_l = \sum_i \left(\frac{R_{ik} + \overline{R}_i}{2}\right)\ln\left(\frac{Y_{ik}}{\tilde{Y}_i}\right) - \sum_i \left(\frac{R_{il} + \overline{R}_i}{2}\right)\ln\left(\frac{Y_{il}}{\tilde{Y}_i}\right) - \sum_j \left(\frac{S_{jk} + \overline{S}_j}{2}\right)\ln\left(\frac{X_{jk}}{\tilde{X}_j}\right) + \sum_j \left(\frac{S_{jl} + \overline{S}_j}{2}\right)\ln\left(\frac{X_{jl}}{\tilde{X}_j}\right) \quad \textbf{(2)}$$

where a bar over a variable indicates the arithmetic mean and a tilde over a variable indicates the geometric mean.

Equation **(2)** can be derived directly from a translog transformation structure by taking the difference between each firm's transformation function and function resulting from averaging arithmetically the transformation functions across all observations. This procedure uses the geometric level of the productivity as the norm. We can derive equation **(2)** in an alternative manner by considering a representative firm that produces the geometric means of the outputs from the geometric means of the inputs. This firm will be in equilibrium when its revenue and cost shares are equal to the arithmetic means computed over the full set of observations being considered. Transitive comparisons are achieved by using this representative firm as the basis for making all possible binary

[5] Diewert (1976) showed that **(1)** can be derived from a homogeneous translog transformation function that is separable in outputs and inputs, and exhibits neutral differences in technology. Caves and Christensen (1980) have shown that separability and neutrality are not required to derive **(1)** from a homogeneous translog transformation function.

comparisons, i.e., any two firms are compared with each other by comparing them both with the representative firm.

To compute the TFP indices for Indian STUs, we have to specify output and input factors used in their production process. Since STUs are involved only in passenger transport business, it is felt that the useful measure of output would be passenger-kilometers. Labor, diesel, and bus can be considered as the three most important inputs to be used in the production process. In relation to the cost of inputs, labor cost is total expenditure on employees; diesel cost is total spending on diesel; and bus cost is sum of maintenance cost (which includes costs on auto spare parts, springs, lubricants, tyres & tubes, batteries, general items, and reconditioned items), interest payment and deprecation. Therefore, total operating cost comprises of labor cost, diesel cost, and bus cost. So, accordingly **(2)** is modified as follows:

$$\ln\left(\frac{TFP_k}{TFP_l}\right) = \ln\left(\frac{Y_k}{Y_l}\right) - \sum_j \left(\frac{S_{jk} + \bar{S}_j}{2}\right) \ln\left(\frac{X_{jk}}{\tilde{X}_j}\right) + \sum_j \left(\frac{S_{jl} + \bar{S}_j}{2}\right) \ln\left(\frac{X_{jl}}{\tilde{X}_j}\right) \quad \textbf{(3)}$$

where specific definitions of the variables are as follows:
TFP = total factor productivity;
Y = output, defined as passenger-kilometers;
S_1 = factor share of labor, defined as total labor cost divided by total operating cost;
S_2 = factor share of diesel, defined as total expenditure on diesel divided by total operating cost;
S_3 = factor share of bus, defined as total bus cost (i.e., sum of maintenance cost, interest payment, and depreciation) divided by total operating cost;
X_1 = total number of employees;
X_2 = total diesel consumed;
X_3 = total number of buses (held); and
Total operating cost is sum of labor cost, diesel cost, and bus cost.

Equation **(3)** is used to compute the TFP indices for sample STUs during 2000s. Although, TFP is the most widely used technique to assess firms' productivity, and has also been used in many transport studies including Caves *et al.* (1981), Caves *et al.* (1987), Gillen, Oum, and Tretheway (1985, 1990), and Encaoua (1991), but the traditional TFP method, however, does not account for changes in the network and production environment. TFP index can be viewed as a measure of gross productivity since the traditional TFP results are based on observed productivity rather than 'true' productive efficiency. Productivity may vary due to differences in production technology, productive efficiency, and network and production environments (Lovell, 1993). Therefore, separating the effects of productive efficiency from those of network and production environment is a basic requirement for making a proper inter-firm efficiency comparison.

Many researchers e.g., Gillen, Oum, and Tretheway (1989), and Ehrlich, Gallais-Hamonno, Liu, and Lutter (1994) used second-stage regression analysis on the TFP index to decompose TFP differentials into various sources, including efficiency. With this method, the TFP index is regressed against a set of explanatory variables. A residual TFP index is then computed by removing the effects of variations in the variables beyond managerial control from the traditional TFP measure. This residual TFP index is used to compare productive efficiency across firms and over time for a firm. We did a similar exercise to compute the residual TFP of sample STUs during 2000s.

3. The Data

Annual data from 2000-01 to 2010-11 for a sample of eleven STUs (Andhra Pradesh State Road Transport Corporation (APSRTC), Maharashtra State Road Transport Corporation (MSRTC), Karnataka State Road Transport Corporation (KnSRTC), North Western Karnataka Road Transport Corporation (NWKnRTC), Gujarat State Road Transport Corporation (GSRTC), Uttar Pradesh State Road Transport Corporation (UPSRTC), Rajasthan State Road Transport Corporation (RSRTC), State Transport Haryana (STHAR), South Bengal State Transport Corporation (SBSTC), Kadamba Transport Corporation Limited (KDTC), and Orissa State Road Transport Corporation (OSRTC)) are used for this study. The primary source of required data is *Performance Statistics of STUs, 2000-01 to 2010-11* published for the Association of State Road Transport Undertakings (ASRTU), New Delhi, India by the Central Institute of Road Transport (CIRT), Pune, India.

Sample STUs are publicly owned, have similar organizational structure, operate throughout their respective jurisdiction (often throughout the state), mainly provide intercity and rural bus transport services, do business in the field of passenger transportation only, produce more or less the same quality of service, but differ in size and the level of out produced. Table 1 presents some recent descriptive statistics of the sample STUs. The size of the undertakings, as measured by passenger-kilometers (PKm) in 2010-11, ranges from 900 million PKm for KDTC to 97393 million PKm for APSRTC. Fleet strength of sample STUs also varies drastically, from 334 buses for OSRTC to 21802 buses for APSRTC. In almost all respect, APSRTC is the largest STU whereas OSRTC is the smallest one.

Table 1. Descriptive Statistics of the Sample STUs during 2010-11

STUs	Pass.-Km (million)	Bus-Km (million)	Pass. carried (million)	No. of employees	No. of buses held
APSRTC	97393	2895.8	4638.8	120566	21802
MSRTC	56098	1897.3	2536.8	104214	16211
KnSRTC	32964	870.8	807.7	34019	7164
NWKnRTC	16526	480.1	697.2	21458	4259
GSRTC	32578	948.5	805.3	40670	7692
UPSRTC	33023	1028.6	470.5	32883	8557
RSRTC	22170	599.2	339.1	20486	4476
STHAR	13480	379.7	418.3	16536	3249
SBSTC	1273	37.8	92.7	2388	507
KDTC	900	28.2	28.6	1881	410
OSRTC	1044	32.2	4.8	930	334

Table 2 presents output indices for sample STUs during 2000s. Output indices are based on passenger-kilometers where all values can be shown relative to any one STU for chosen year. We have chosen APSRTC, the largest STU, in 2000-01 as reference. Among sample STUs, UPSRTC, KnSRTC, and APSRTC achieved significant growth in their output during 2000s; they grew at the rate of 4.55%, 3.89%, and 3.25% per year respectively. However, GSRTC and MSRTC faced decline whereas NWKnRTC and STHAR experienced negligible increase in their output during the sample period. Other STUs experienced moderate increase in their output ranging from 1.06% per year for OSRTC to 2.84% per year for SBSTC.

Table 3 presents aggregate input indices (X_k's), which are based on the following equation: $\ln\left(\frac{X_k}{X_l}\right) = \sum_j \left(\frac{S_{jk} + \bar{S}_j}{2}\right) \ln\left(\frac{X_{jk}}{\tilde{X}_j}\right) - \sum_j \left(\frac{S_{jl} + \bar{S}_j}{2}\right) \ln\left(\frac{X_{jl}}{\tilde{X}_j}\right)$, where variables and notations have their previous meanings. Among sample STUs, only three STUs, KnSRTC, NWKnRTC, and APSRTC used more inputs in 2010-11 than what they used in 2000-01. All other STUs experienced decline in their input use; decline in input use is tremendous in OSRTC (4.89% per year) and GSRTC (3.58% per year) during the 2000s. Other STUs experienced moderate decline in their input use ranging from 0.01% per year for KDTC to 1.17% per year for STHAR.

Table 2. Output of STUs, 2000-01 to 2010-11, Indices; APSRTC (2000-01) = 1.000

STUs	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR[6] (%)
APSRTC	1.000	0.954	1.054	1.026	1.086	1.160	1.242	1.309	1.414	1.378	1.377	3.25
MSRTC	0.803	0.791	0.764	0.719	0.727	0.692	0.669	0.729	0.753	0.756	0.793	-0.12
KnSRTC	0.318	0.297	0.295	0.325	0.324	0.341	0.377	0.421	0.430	0.431	0.466	3.89
NWKnRTC	0.223	0.231	0.236	0.236	0.228	0.213	0.218	0.250	0.242	0.231	0.234	0.45
GSRTC	0.549	0.523	0.499	0.415	0.386	0.376	0.412	0.450	0.473	0.467	0.461	-1.75
UPSRTC	0.299	0.294	0.308	0.321	0.332	0.348	0.373	0.399	0.426	0.451	0.467	4.55
RSRTC	0.240	0.242	0.257	0.269	0.288	0.294	0.300	0.306	0.306	0.317	0.313	2.69
STHAR	0.190	0.203	0.199	0.198	0.199	0.205	0.208	0.195	0.222	0.202	0.191	0.03
SBSTC	0.014	0.014	0.015	0.013	0.013	0.013	0.015	0.015	0.016	0.018	0.018	2.84
KDTC	0.011	0.012	0.012	0.013	0.013	0.014	0.013	0.012	0.011	0.012	0.013	1.35
OSRTC	0.013	0.012	0.012	0.011	0.012	0.012	0.012	0.012	0.014	0.015	0.015	1.06

Table 3. Input of STUs, 2000-01 to 2010-11, Indices; APSRTC (2000-01) = 1.000

STUs	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR (%)
APSRTC	1.000	0.977	0.975	0.956	0.961	0.965	0.978	0.983	0.979	0.999	1.045	0.44
MSRTC	0.903	0.890	0.866	0.846	0.853	0.828	0.820	0.827	0.824	0.845	0.867	-0.41
KnSRTC	0.261	0.217	0.220	0.221	0.231	0.249	0.278	0.295	0.330	0.344	0.352	3.07
NWKnRTC	0.180	0.184	0.185	0.185	0.174	0.174	0.200	0.224	0.233	0.215	0.204	1.22
GSRTC	0.505	0.484	0.466	0.452	0.425	0.408	0.398	0.402	0.365	0.350	0.351	-3.58
UPSRTC	0.356	0.346	0.346	0.326	0.309	0.325	0.327	0.346	0.340	0.352	0.354	-0.05
RSRTC	0.232	0.223	0.224	0.223	0.219	0.223	0.225	0.220	0.217	0.217	0.214	-0.82
STHAR	0.179	0.176	0.177	0.174	0.171	0.169	0.165	0.161	0.152	0.163	0.159	-1.17
SBSTC	0.024	0.024	0.024	0.023	0.023	0.022	0.023	0.022	0.022	0.022	0.022	-0.94
KDTC	0.017	0.017	0.016	0.017	0.017	0.018	0.018	0.017	0.017	0.017	0.016	-0.01
OSRTC	0.021	0.016	0.014	0.013	0.012	0.013	0.012	0.012	0.013	0.013	0.013	-4.89

[6] CAGR signifies compound annual growth rate during the sample period. Throughout this paper, we follow the convention that growth is continuously compounded. Compounded percentage growth rates are rounded-off after two decimal points.

4. Total Factor Productivity: Analysis and Results

Using equation **(3)**, TFP indices, which are widely used measure of gross productivity, are computed for sample STUs. These indices, normalized so that the level of TFP for APSRTC in 2000-01 is 1.000, are presented in Table 4 along with their compound annual growth rate (CAGR) from the year 2000-01 to 2010-11. In Table 5 we rank the STUs by their level of TFP in 2000-01 and 2010-11. In the same Table, we also include STUs' rank according to a measure of their size and growth in their TFP and output. The wide disparity in growth rates over the period 2000-01 to 2010-11 resulted in substantial changes in the ranking of the firms. For example, from 2000-01 to 2010-11 period RSRTC rose from 5th to 1st rank, UPSRTC rose from 8th to 3rd rank, APSRTC rose from 6th to 4th rank, OSRTC rose from 10th to 8th rank, and SBSTC rose from 11th to 10th rank while NWKnRTC fell from 1st to 7th rank, GSRTC fell from 3rd to 5th rank, STHAR fell from 4th to 6th rank, MSRTC fell from 7th to 9th rank, and KDTC fell from 9th to 11th rank. During the sample period, KnSRTC seems to be the most consistent performer. It was the 2nd most productive STU during the year 2000-01 and 2010-11. In fact, it was the most productive firm from 2001-02 to 2007-08.

Table 4. TFP of STUs, 2000-01 to 2010-11, Indices; APSRTC (2000-01) = 1.000

STUs	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR (%)
APSRTC	1.000	0.976	1.081	1.073	1.130	1.202	1.270	1.331	1.444	1.379	1.318	2.80
MSRTC	0.889	0.889	0.883	0.850	0.852	0.836	0.816	0.882	0.913	0.895	0.915	0.29
KnSRTC	1.221	1.369	1.344	1.470	1.403	1.371	1.357	1.427	1.301	1.252	1.322	0.80
NWKnRTC	1.238	1.258	1.274	1.276	1.310	1.220	1.089	1.117	1.038	1.075	1.147	-0.76
GSRTC	1.089	1.080	1.070	0.918	0.907	0.921	1.034	1.120	1.297	1.335	1.314	1.90
UPSRTC	0.841	0.849	0.891	0.985	1.075	1.072	1.140	1.155	1.253	1.283	1.319	4.60
RSRTC	1.035	1.082	1.147	1.205	1.314	1.321	1.332	1.391	1.408	1.460	1.465	3.54
STHAR	1.062	1.150	1.127	1.138	1.167	1.209	1.255	1.214	1.464	1.244	1.199	1.22
SBSTC	0.558	0.586	0.607	0.570	0.574	0.598	0.651	0.667	0.720	0.819	0.811	3.81
KDTC	0.674	0.736	0.752	0.776	0.730	0.777	0.727	0.717	0.686	0.715	0.771	1.36
OSRTC	0.623	0.755	0.883	0.885	0.939	0.965	0.943	1.022	1.068	1.126	1.143	6.25

Table 5. STUs ranked by 2000-01 & 2010-11 level of TFP and Size

STUs	TFP rank	TFP level	TFP rank	TFP level	TFP CAGR		Output rank	Output level	Output rank	Output level	Output CAGR	
	2000-01	2000-01	2010-11	2010-11	rank	level (%)	2000-01	2000-01	2010-11	2010-11	rank	level (%)
APSRTC	6	1.000	4	1.318	5	2.80	1	1.000	1	1.377	3	3.25
MSRTC	7	0.889	9	0.915	10	0.29	2	0.803	2	0.793	10	-0.12
KnSRTC	2	1.221	2	1.322	9	0.80	4	0.318	3	0.466	2	3.89
NWKnRTC	1	1.238	7	1.147	11	-0.76	7	0.223	7	0.234	8	0.45
GSRTC	3	1.089	5	1.314	6	1.90	3	0.549	5	0.461	11	-1.75
UPSRTC	8	0.841	3	1.319	2	4.60	5	0.299	4	0.467	1	4.55
RSRTC	5	1.035	1	1.465	4	3.54	6	0.240	6	0.313	5	2.69
STHAR	4	1.062	6	1.199	8	1.22	8	0.190	8	0.191	9	0.03

SBSTC	11	0.558	10	0.811	3	3.81	9	0.014	9	0.018	4	2.84
KDTC	9	0.674	11	0.771	7	1.36	11	0.011	11	0.013	6	1.35
OSRTC	10	0.623	8	1.143	1	6.25	10	0.013	10	0.015	7	1.06

It seems that there is a positive, though not very strong, relationship between TFP and size of STUs (see, Figure 1). Correlation coefficient between TFP and size of STUs (measured in terms of passenger-kilometers) is 0.360 with t-statistic of 4.21, which shows that the coefficient is statistically significant at 1% level of significance.[7]

In terms of TFP growth, the STUs fall in four distinct categories. Four STUs, OSRTC (6.25%), UPSRTC (4.60%), SBSTC (3.81%), and RSRTC (3.54%) achieved very high growth rate of productivity. Four STUs achieved productivity growth that was relatively modest ranging from 1.22% per year (STHAR) to 2.80% per year (APSRTC) from 2000-01 to 2010-11. Two STUs, MSRTC (0.29%) and KnSRTC (0.80%), achieved low productivity growth whereas one STU, NWKnRTC (-0.76%) faced decline in its productivity during the sample period.

Estimates of TFP can be compared with more traditional indicators of transport productivity e.g., labor productivity through passenger-kilometers per employee (PKm/E), fuel productivity through bus-kilometers per liter of diesel (BKm/D), and bus productivity through bus-kilometers per bus held (BKm/B). We present these partial factor productivity indices from the period 2000-01 to 2010-11 in Table 6 (labor productivity), Table 7 (fuel productivity), and Table 8 (bus productivity), along with their compound annual growth rate over the sample period. In Table 9, we present the 2000-01 and 2010-11 rankings of the STUs based on their labor productivity, fuel productivity, bus productivity, and total factor productivity.

During the year 2010-11, OSRTC experienced highest level of labor productivity, 1.12 million passenger-km per employee, whereas KDTC faced the lowest level, 0.48 million passenger-km per employee. It is interesting to note that OSRTC has also achieved highest growth in labor productivity from 2000-01 to 2010-11. This is the main reason why total factor productivity performance of OSRTC has improved drastically during the same period. UPSRTC has also achieved tremendous improvement in its labor productivity from 2000-01 (0.45 million passenger-km per employee) to 2010-11 (1.00 million passenger-km per employee). As a result, like OSRTC, UPSRTC has also achieved significant improvement in its total factor productivity performance during the sample period.

There is a high degree of positive correlation between TFP and PKm/E indices. Correlation coefficient between TFP and PKm/E is 0.930 with t-statistic of 27.66. However, correlation coefficient between TFP and BKm/D (0.738 with t-statistic of 11.93) and TFP and BKm/B (0.887 with t-statistic of 20.97) is relatively modest. As a consequence, similarities in rankings drawn from TFP and PKm/E indices are relatively high but TFP and BKm/D indices and TFP and BKm/B indices are relatively modest. As a whole, although there are some similarities among these indices, there are some major

[7] A simple method to test the null hypothesis that the correlation coefficient is zero can be obtained using Student's t-test on the t-statistic $= r\sqrt{\frac{N-2}{1-r^2}}$, df = N-2; where r is correlation coefficient and N is the number of observations. So, in this case when r = 0.360 and N-2 = 119, t-statistic = 4.21. Hence, we can reject the null hypothesis that the correlation coefficient is zero at 1% level of significance since critical t-value is 2.62. Therefore, we can infer at 1% level of significance that the two series are correlated and the non-zero correlation did not happen by chance.

differences as well. We found that in 2010-11, APSRTC and UPSRTC have almost the same level of total factor productivity and fuel productivity, though APSRTC's labor productivity is almost 20% less and bus productivity is 10% higher than that of UPSRTC (Table 9). In 2010-11, RSRTC ranks first on the basis of TFP and bus productivity whereas in terms of labor productivity and fuel productivity, OSRTC and GSRTC rank first, respectively.

Table 6. Labor Productivity (PKm per Employee) of STUs, 2000-01 to 2010-11, Indices; APSRTC (2000-01) = 1.000

STUs	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR (%)
APSRTC	1.000	0.972	1.110	1.108	1.191	1.288	1.385	1.487	1.606	1.531	1.471	3.93
MSRTC	0.922	0.923	0.922	0.898	0.901	0.865	0.843	0.932	0.988	0.963	0.980	0.61
KnSRTC	1.699	1.651	1.609	1.773	1.670	1.766	1.781	1.973	1.725	1.666	1.764	0.38
NWKnRTC	1.382	1.416	1.446	1.426	1.431	1.369	1.247	1.342	1.232	1.384	1.402	0.14
GSRTC	1.156	1.138	1.102	0.981	0.955	0.968	1.121	1.301	1.461	1.501	1.459	2.35
UPSRTC	0.814	0.823	0.891	1.096	1.174	1.201	1.346	1.456	1.604	1.812	1.829	8.44
RSRTC	1.237	1.275	1.397	1.492	1.638	1.693	1.773	1.881	1.911	2.000	1.971	4.76
STHAR	1.249	1.364	1.362	1.346	1.399	1.463	1.552	1.508	1.906	1.493	1.484	1.74
SBSTC	0.592	0.624	0.650	0.579	0.605	0.665	0.770	0.779	0.858	0.974	0.970	5.07
KDTC	0.743	0.810	0.825	0.846	0.800	0.885	0.816	0.801	0.771	0.798	0.871	1.61
OSRTC	0.490	0.660	0.981	1.046	1.131	1.248	1.250	1.432	1.721	1.960	2.043	15.35

Table 7. Fuel Productivity (Bus-Km per Litre of Diesel) of STUs, 2000-01 to 2010-11, Indices; APSRTC (2000-01) = 1.000

STUs	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR (%)
APSRTC	1.000	0.998	1.031	1.057	1.041	1.037	1.035	1.030	1.033	1.039	1.018	0.18
MSRTC	0.917	0.925	0.937	0.947	0.955	0.963	0.970	0.970	0.970	0.970	0.970	0.57
KnSRTC	0.919	0.961	0.988	1.033	1.039	1.010	0.998	0.988	0.969	0.953	0.955	0.38
NWKnRTC	0.978	0.988	1.010	1.053	1.055	1.033	1.030	1.004	0.998	0.986	0.990	0.12
GSRTC	1.043	1.043	1.043	1.031	1.022	1.024	1.033	1.051	1.089	1.093	1.089	0.43
UPSRTC	0.929	0.949	0.943	0.961	0.990	1.016	1.049	1.045	1.047	1.047	1.047	1.20
RSRTC	0.949	0.961	0.972	0.976	0.984	1.002	0.984	0.978	0.980	0.992	0.994	0.47
STHAR	0.872	0.878	0.894	0.921	0.961	0.972	0.990	0.978	0.965	0.945	0.941	0.77
SBSTC	0.683	0.728	0.762	0.795	0.805	0.827	0.811	0.805	0.799	0.795	0.795	1.53
KDTC	0.815	0.827	0.839	0.884	0.907	0.880	0.898	0.872	0.858	0.896	0.872	0.68
OSRTC	0.787	0.811	0.819	0.839	0.866	0.866	0.866	0.866	0.866	0.896	0.915	1.52

Table 8. Bus Productivity (Bus-Km per Bus Held) of STUs, 2000-01 to 2010-11, Indices; APSRTC (2000-01) = 1.000

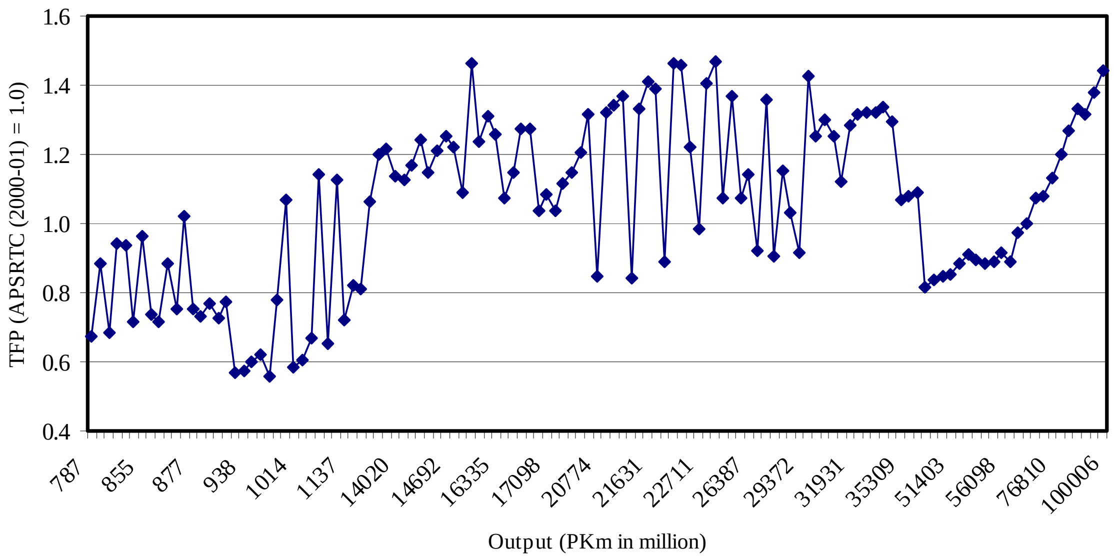
STUs	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR (%)
APSRTC	1.000	0.943	1.015	1.037	1.053	1.062	1.100	1.121	1.142	1.134	1.155	1.45
MSRTC	0.923	0.923	0.930	0.952	0.980	0.950	0.983	1.007	1.005	1.007	1.018	0.99
KnSRTC	0.848	1.080	1.096	1.112	1.106	1.070	1.029	1.053	1.037	1.047	1.057	2.23
NWKnRTC	1.025	1.057	1.060	1.067	1.043	0.992	0.996	1.007	1.006	0.975	0.981	-0.44

GSRTC	1.017	1.009	0.975	0.983	0.950	0.954	1.014	1.075	1.153	1.114	1.073	0.53
UPSRTC	0.769	0.818	0.833	0.876	0.936	0.999	1.020	1.050	1.062	1.092	1.046	3.12
RSRTC	0.959	0.992	1.015	1.023	1.056	1.131	1.166	1.184	1.152	1.176	1.164	1.96
STHAR	0.963	0.978	0.989	1.039	1.100	1.119	1.054	1.036	1.111	1.041	1.017	0.55
SBSTC	0.566	0.596	0.592	0.688	0.645	0.674	0.759	0.557	0.608	0.666	0.649	1.38
KDTC	0.640	0.645	0.652	0.690	0.677	0.656	0.608	0.610	0.621	0.618	0.598	-0.69
OSRTC	0.640	0.787	0.873	0.850	0.862	0.865	0.816	0.894	0.917	0.888	0.838	2.73

Table 9. STUs ranked by Labor Productivity (PKm/E), Fuel Productivity (BKm/D), Bus Productivity (BKm/B), and Total Factor Productivity

STUs	PKm/E 2000-01		PKm/E 2010-11		BKm/D 2000-01		BKm/D 2010-11		BKm/B 2000-01		BKm/B 2010-11		TFP 2000-01		TFP 2010-11	
	Rank	Level	Rank	Level	Rank	Level	Rank	Rank	Rank	Rank	Rank	Level	Rank	Level	Rank	Level
APSRTC	6	1.000	6	1.471	2	1.000	3	1.018	3	1.000	2	1.155	6	1.000	4	1.318
MSRTC	7	0.922	9	0.980	7	0.917	6	0.970	6	0.923	6	1.018	7	0.889	9	0.915
KnSRTC	1	1.699	4	1.764	6	0.919	7	0.955	7	0.848	4	1.057	2	1.221	2	1.322
NWKnRTC	2	1.382	8	1.402	3	0.978	5	0.990	1	1.025	8	0.981	1	1.238	7	1.147
GSRTC	5	1.156	7	1.459	1	1.043	1	1.089	2	1.017	3	1.073	3	1.089	5	1.314
UPSRTC	8	0.814	3	1.829	5	0.929	2	1.047	8	0.769	5	1.046	8	0.841	3	1.319
RSRTC	4	1.237	2	1.971	4	0.949	4	0.994	5	0.959	1	1.164	5	1.035	1	1.465
STHAR	3	1.249	5	1.484	8	0.872	8	0.941	4	0.963	7	1.017	4	1.062	6	1.199
SBSTC	10	0.592	10	0.970	11	0.683	11	0.795	11	0.566	10	0.649	11	0.558	10	0.811
KDTC	9	0.743	11	0.871	9	0.815	10	0.872	9	0.640	11	0.598	9	0.674	11	0.771
OSRTC	11	0.490	1	2.043	10	0.787	9	0.915	10	0.640	9	0.838	10	0.623	8	1.143

Figure 1. Relationship between TFP and Output of STUs during 2000s



Although, there is a direct link between productivity, price recovery (ratio of output price to aggregate input price), and profitability, it is easy to show that productivity growth and strong financial performance do not necessarily go together. Productivity and profitability would move together in the same direction if and only if input factor prices in comparison to output prices are unchanged. We tried to find out whether productive STUs in India are profitable or not. Profitability performance of any organization depends on revenue in comparison to costs. Here in this case, revenue has two components – traffic revenue and non-traffic revenue. Traffic revenue is nothing but total earnings from passengers whereas non-traffic revenue includes earnings from advertisement, shops in depot, subsidy from local government for providing concessional travel facility to students, freedom fighters, elected representatives, senior citizens, journalists, etc., and any other revenue from non-core business. Non-traffic revenue component of total revenue is not homogenous across STUs. For example, during the year 2010-11, non-traffic revenue for UPSRTC was only 1.7% of its total revenue whereas it was more than 15% of the total revenue for APSRTC, MSRTC, GSRTC, SBSTC, and KDTC. As far as cost in STUs is concerned, it depends on personnel cost, fuel (diesel) cost, capital (bus) cost including maintenance cost and interest payment, and taxes paid to the government. Taxes, which include passenger tax, motor vehicle tax, and other miscellaneous taxes, are also not homogenous across STUs. For example, during the year 2010-11, it varied from 0.6% of total cost for SBSTC to 15.4% of total cost for MSRTC. Since non-traffic revenue component of total revenue and tax component of total cost is not homogenous across STUs, total revenue minus total cost (or a ratio of total revenue to total cost) would measure financial profitability rather than economic profitability. To make a proper inter-firm comparison of profitability, heterogeneous component of both revenue and costs should be excluded. Since traffic revenue and operating cost is homogenous across STUs, to make a proper inter-firm comparison we can define economic profitability as traffic revenue minus operating cost (or a ratio of traffic revenue to operating cost).

Table 10 presents financial as well as economic profitability of STUs for the year 2000-01 and 2010-11. This table reveals that profitability performance varies greatly among the sample STUs. During the year 2010-11, OSRTC is the only STU, which experienced both financial as well as economic profit. It is important to note that, among the sample STUs, OSRTC experienced the highest productivity growth during 2000s. Among the sample STUs, only three firms – MSRTC, KnSRTC, and OSRTC could experience financial profit and only two firms – UPSRTC and OSRTC could experience economic profit during the year 2010-11. All other STUs incurred huge losses during the same year. Financial loss during 2010-11 varied from Rs. 93 million for SBSTC to Rs. 4189 million for GSRTC whereas economic loss during the same year varied from Rs. 407 million for KDTC to Rs. 8663 million for APSRTC. Table 10 reveals that except UPSRTC and OSRTC, none of the sample STUs could improve their economic profitability whereas seven STUs – APSRTC, MSRTC, KnSRTC, GSRTC, UPSRTC, SBSTC and OSRTC could improve their financial profitability during 2000s.

As discussed earlier, there is a direct link between total factor productivity, price recovery, and profitability. Since, total factor productivity is defined as a ratio of output quantity to aggregate input quantity and price recovery is defined as a ratio of output price to aggregate input price; for STUs, total factor productivity multiplied by price recovery will be a ratio of traffic revenue to operating cost. Ratio of traffic revenue to operating cost is nothing but profitability, to be precise, economic profitability. Therefore, economic profitability is positively related with both total factor productivity and price recovery.

Table 11 presents output price index, input price index, and price recovery index for sample STUs for the year 2000-01 and 2010-11. In this case, output price index is constructed by dividing traffic revenue index by the output quantity index. Similarly, the input price index is calculated by dividing operating cost index by the aggregate input quantity index. This table reveals that none of the STUs could increase their output price (i.e., fare) in line with the increase in their input factor prices during 2000s. That's why, between 2000-01 and 2010-11, all the STUs faced decline in their price recovery varying from 3.4% for NWKnRTC to 40.3% for KDTC.

Decline in price recovery is the main reason why only two out of eleven sample STUs, UPSRTC and OSRTC, could improve their economic profitability from 2000-01 to 2010-11. Between 2000-01 and 2010-11, profitability improvement in UPSRTC (34.3%) and OSRTC (59.0%) was primarily due to tremendous productivity growth achieved by them (UPSRTC (56.8%) and OSRTC (83.5%)). Although, except NWKnRTC, all the STUs could improve their productivity, none of them except UPSRTC and OSRTC could improve their economic profitability. From 2000-01 to 2010-11, APSRTC, MSRTC, KnSRTC, NWKnRTC, GSRTC, RSRTC, STHAR, SBSTC, and KDTC faced decline in their economic profitability by 16.6%, 2.5%, 5.7%, 10.6%, 25.3%, 5.4%, 27.9%, 2.0%, and 25.1%, respectively. This is mainly because none of them could increase their output price in line with the increase in their input factor prices.

Table 10. Financial and Economic Profitability of STUs during 2000-01 and 2010-11 (monetary units in Rs. million)

STUs	Traffic Revenue (TrR)		Total Revenue (TR)		Operating Cost (OC)		Total Cost (TC)		Economic Profit (TrR/OC)		Financial Profit (TR/TC)	
	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11
APSRTC	24484	52055	25402	61457	23815	60718	27502	64631	1.028	0.857	0.924	0.951
MSRTC	22644	40751	25336	49680	22637	41798	26323	49387	1.000	0.975	0.962	1.006
KnSRTC	6696	17690	7084	20786	6850	19190	7244	20166	0.978	0.922	0.978	1.031
NWKnRTC	4410	9048	4725	10326	4441	10184	4674	10630	0.993	0.888	1.011	0.971
GSRTC	11984	14045	12485	19785	13823	21673	15665	23974	0.867	0.648	0.797	0.825
UPSRTC	6775	20386	7385	20744	8289	18587	8364	21129	0.817	1.097	0.883	0.982
RSRTC	5655	11712	5881	12174	5878	12876	6715	14116	0.962	0.910	0.876	0.862
STHAR	4779	7840	4953	8597	4295	9766	5675	11370	1.113	0.803	0.873	0.756
SBSTC	283	626	486	1345	633	1430	634	1438	0.447	0.438	0.766	0.936
KDTC	300	564	354	829	387	971	392	986	0.776	0.581	0.903	0.841
OSRTC	259	558	300	655	399	539	417	584	0.651	1.035	0.720	1.122

Table 11. Output Price, Input Price, and Price Recovery Indices of STUs during 2000-01 and 2010-11 (APSRTC (2000-01) = 1.000)

STUs	Output Price		Input Price		Price Recovery (Output Price / Input Price)	
	2000-01	2010-11	2000-01	2010-11	2000-01	2010-11
APSRTC	1.000	1.544	1.000	2.440	1.000	0.633
MSRTC	1.152	2.099	1.053	2.024	1.094	1.037
KnSRTC	0.860	1.550	1.102	2.289	0.780	0.677
NWKnRTC	0.808	1.579	1.036	2.096	0.780	0.753
GSRTC	0.892	1.244	1.149	2.593	0.776	0.480

UPSRTC	0.925	1.783	0.978	2.205	0.946	0.809
RSRTC	0.962	1.528	1.064	2.527	0.905	0.605
STHAR	1.027	1.676	1.008	2.579	1.020	0.650
SBSTC	0.826	1.422	1.107	2.730	0.746	0.521
KDTC	1.116	1.773	0.957	2.549	1.166	0.696
OSRTC	0.815	1.519	0.797	1.741	1.023	0.873

We also calculated gross productivity indices for the Indian bus industry. Aggregate data of the industry is used to compute its productivity. Table 12 presents gross productivity indices along with labor productivity (passenger-kilometers per employee), fuel productivity (bus-kilometers per litre of diesel), and bus productivity (bus-kilometers per bus held) indices for the industry. First row of Table 12 presents TFP indices based on Caves, Christensen, and Diewert (1982) index (equation **(2)**) whereas second row presents TFP indices based on Tornqvist-Theil index, the discrete Divisia index (equation **(1)**). Third, fourth, and fifth row reports labor productivity, fuel productivity, and bus productivity, respectively. According to the first measure of productivity i.e., Caves, Christensen, and Diewert (1982) based TFP indices, compound annual growth rate of productivity in the industry is found to be 2.66% during 2000s. Productivity growth was almost the same when discrete Divisia index (based on equation **(1)**) was used to compute the TFP indices. Compound annual growth rate of labor productivity (3.65%) is quite high as compared to fuel productivity (0.83%) and bus productivity (1.02%) during 2000s. All measures of productivity show an improvement in industry performance from 2000-01 to 2010-11.

Table 12. Productivity of Indian Bus Transport Industry, Indices; Productivity (2000-01) = 1.000

	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR (%)
TFP (CCD)	1.000	1.011	1.047	1.069	1.090	1.123	1.156	1.220	1.262	1.291	1.300	2.66
TFP (D)	1.000	1.011	1.047	1.068	1.090	1.122	1.156	1.218	1.260	1.289	1.298	2.64
PKm/E	1.000	1.008	1.046	1.085	1.109	1.155	1.200	1.293	1.350	1.343	1.432	3.65
BKm/D	1.000	1.000	1.031	1.040	1.051	1.066	1.086	1.088	1.099	1.086	1.086	0.83
BKm/B	1.000	0.994	1.041	1.059	1.071	1.078	1.100	1.118	1.122	1.127	1.107	1.02

5. Residual Total Factor Productivity: Analysis and Results

As discussed earlier, the traditional TFP results are based on observed productivity rather than ‘true’ productive efficiency. Productivity may vary due to differences in production technology, productive efficiency, and network and production environments (Lovell, 1993). Therefore, separating effects of productive efficiency from those of network and production environment is a basic requirement for making a proper inter-firm efficiency comparison. We use second-stage regression analysis on the TFP indices to compute the residual TFP indices which can be used to make a proper inter-firm productive efficiency comparison. Thus, to compute the residual TFP, total factor productivity indices are regressed against a set of explanatory variables.[8] Residual TFP indices are then computed by removing the effects of variations in the variables beyond managerial control from the traditional TFP measures. In this study, productive efficiency of STUs is measured in terms of residual TFP index.

We run a log-linear regression where (natural log) of TFP indices are regressed against (natural log) of output[9], (natural log) of average fare[10], (natural log) of passenger lead[11], load factor[12], and fleet utilization[13] to compute the residual TFP indices for sample STUs over the sample period. It is felt that the variables, output, average fare, and passenger lead, are usually beyond the managerial control of the STUs. In general, the level of output is exogenously fixed by the respective state governments and STUs take it as given; fare revision is a cumbersome process and due to absence of any automatic fare revision formula accepted by the state governments, STUs find it difficult to revise their fare in line with the increase in their input factor prices; and passenger lead, which is a good proxy for average length of haul, can also be considered exogenous since the distance between bus stops is usually decided by the state governments.[14] Therefore, we consider output, average fare, and passenger lead as ‘uncontrollable’ variables. Table 13 reports eight alternative regression models primarily based on fixed effects model of panel data method. Econometricians have recognized that it is important in the analysis of panel data (cross sections of time series) to allow for effects related to each time period and to each cross-section unit. Here these effects represent differences in TFP associated with firms and with time that are not accounted for by differences in output, average fare, passenger lead, load factor, and fleet utilization.

Among eight models presented in Table 13, TFP8 is nested in TFP7, and is not statistically dominated by TFP7. The log likelihood ratio test between TFP8 and TFP7 yields a test statistic of 0.56 (=2*(179.12-178.84)), which is significantly lower than 3.84 – the critical value of χ^2 distribution with 1 degree of freedom at 5% level of significance. Similarly, TFP6 is nested in TFP5, and is statistically dominated by TFP5. The log likelihood ratio test between TFP6 and TFP5 yields a test statistic of 27.20 (=2*(180.09-166.49)), which is significantly higher than 3.84 – the critical value of χ^2 distribution with 1 degree of freedom at 5% level of significance. Therefore, TFP5 is statistically preferred over TFP6. Since TFP8 is nested in TFP5, we can find out whether TFP5 is statistically superior to TFP8 or not. The log likelihood ratio test between TFP5 and TFP8 yields a test statistic of 2.50, which is significantly lower than 5.99 – the critical value of χ^2 distribution with 2 degrees of freedom at 5% level of significance. Therefore, none of the three models – TFP5, TFP6, and TFP7 are statistically preferred over TFP8.

Models from TFP5 to TFP8 are slightly different than models from TFP1 to TFP4. TFP1 to TFP4 models include firm specific dummies and firm specific time trends whereas TFP5 to TFP8 models include firm specific and time specific dummies.

[8] The statistical program NLOGIT 3.0 is used for the estimation of different models.
[9] Measured in million passenger-km.
[10] Measured in Rs. per passenger-km.
[11] Measured in kilometer. Passenger lead indicates the average length of journey performed by passengers.
[12] Measured in percentage. It is defined as the ratio of revenue passenger-kilometers to available passenger-kilometers.
[13] Measured in percentage. It is defined as the ratio of the number of buses on road to the fleet held by the STU.
[14] A bus stop is a designated place where buses stop for passengers to board or leave a bus.

According to R-square and log-likelihood values, TFP1 to TFP4 models perform better than TFP5 to TFP8 models. Now, we can find out which model from TFP1 to TFP4 is the best model to use for estimating the residual TFP of STUs. Since TFP2 is nested in TFP1, we can find out whether TFP2 is statistically dominated by TFP1 or not. The log likelihood ratio test between TFP1 and TFP2 yields a test statistic of 33.54 (=2*(228.44-211.67)), which is significantly higher than 3.84 – the critical value of χ^2 distribution with 1 degree of freedom at 5% level of significance. Hence, TFP2 is statistically dominated by TFP1. Similarly, TFP4 is nested in TFP3, and is statistically dominated by TFP3. The log likelihood ratio test between TFP3 and TFP4 yields a test statistic of 7.24 (=2*(228.40-224.78)), which is significantly higher than 3.84 – the critical value of χ^2 distribution with 1 degree of freedom at 5% level of significance. Moreover, a comparison between TFP3 and TFP1 shows that TFP3 is not statistically dominated by TFP1. The log likelihood ratio test between TFP1 and TFP3 yields a test statistic of 0.08 (=2*(228.44-228.40)), which is significantly lower than 3.84 – the critical value of χ^2 distribution with 1 degree of freedom at 5% level of significance. Hence, none of the models presented in Table 13 performs better than TFP3. Therefore, TFP3 is used to compute the residual TFP indices for sample STUs over the sample period.

TFP3 includes four variables (output, average fare, load factor, and fleet utilization) with both firm-specific intercept and firm-specific time trends. The variable passenger lead is found to be statistically insignificant both according to t-statistic (refer TFP1 and TFP2) and log-likelihood ratio test. The regression results of TFP3 presented in equation **(4)** reveal that different STUs have different residual TFP levels and growth rates over time. The statistically significant positive coefficient of natural log of output indicates that, *ceteris paribus*, there is a positive relationship between STUs' gross productivity level and their volume of operation. The set of plausible explanations include productivity gains resulting from the filling of excess capacity, large firm size, and learning by doing effects. The statistically significant negative coefficient of natural log of average fare indicates that, *ceteris paribus*, there is a negative relationship between STUs' gross productivity level and their average fare. This may be because when average fare is increased, demand falls and consequently output produced falls even if the same level of input factors is used. Therefore, *ceteris paribus*, productivity falls when fare is increased. The statistically significant positive coefficient of load factor suggests that filling of excess capacity is at least a partial explanation for the growth of gross productivity. Equation **(4)** also shows that the coefficient of fleet utilization is positive and statistically significant, which implies that the STUs' fleet utilization and their gross productivity is closely linked.

$$\begin{aligned}
\ln TFP = & -\underset{(7.70)}{1.946} + \underset{(2.07)}{0.040} \ln(Output) - \underset{(5.50)}{0.366} \ln(AverageFare) + \underset{(2.42)}{0.003}\ LoadFactor \\
& + \underset{(7.45)}{0.011}\ FleetUtilization + \underset{(0.55)}{0.022}\ MSRTC + \underset{(7.36)}{0.338}\ KnSRTC \\
& + \underset{(5.84)}{0.287}\ NWKnRTC + \underset{(2.72)}{0.115}\ GSRTC - \underset{(1.87)}{0.086}\ UPSRTC + \underset{(3.60)}{0.162}\ RSRTC \\
& + \underset{(3.73)}{0.179}\ STHAR - \underset{(1.46)}{0.146}\ SBSTC + \underset{(1.17)}{0.106}\ KDTC - \underset{(0.34)}{0.033}\ OSRTC \\
& + \underset{(5.11)}{0.023}\ APSRTC \times Time + \underset{(2.28)}{0.009}\ MSRTC \times Time + \underset{(1.41)}{0.006}\ KnSRTC \times Time \\
& - \underset{(1.21)}{0.005}\ NWKnRTC \times Time + \underset{(5.22)}{0.023}\ GSRTC \times Time + \underset{(8.89)}{0.038}\ UPSRTC \times Time \\
& + \underset{(6.66)}{0.028}\ RSRTC \times Time + \underset{(3.40)}{0.014}\ STHAR \times Time + \underset{(9.24)}{0.040}\ SBSTC \times Time \\
& + \underset{(2.89)}{0.012}\ KDTC \times Time + \underset{(10.78)}{0.046}\ OSRTC \times Time;
\end{aligned} \tag{4}$$

$R^2 = 0.979$, adj $R^2 = 0.973$, $N = 121$, $df = 95$,

t - values are given in parentheses.

Table 13. TFP Regression Results (dependent variable: natural log of TFP)[15]

Parameter	TFP1	TFP2	TFP3	TFP4	TFP5	TFP6	TFP7	TFP8
Constant	-1.940	-2.047	-1.946	-1.892	-2.899	-5.770	-2.896	-2.916
	(7.60)	(7.04)	(7.70)	(7.33)	(8.36)	(6.28)	(8.33)	(8.45)
natural log of Output	0.039	0.057	0.040	0.048	0.062	0.364	0.059	0.064
	(2.03)	(2.64)	(2.07)	(2.48)	(2.24)	(4.10)	(2.14)	(2.44)
natural log of Average Fare	-0.366		-0.366	-0.417	-0.513		-0.514	-0.531
	(5.48)		(5.50)	(6.45)	(5.93)		(5.92)	(6.45)
natural log of Passenger Lead	-0.009	-0.006			0.040	0.060		
	(0.26)	(0.15)			(1.24)	(1.70)		
Load Factor	0.003	0.005	0.003		0.001	0.001	0.001	
	(2.41)	(3.77)	(2.42)		(0.50)	(0.76)	(0.67)	
Fleet Utilization	0.012	0.011	0.011	0.011	0.018	0.015	0.019	0.020
	(6.65)	(5.71)	(7.45)	(7.17)	(7.46)	(5.46)	(8.81)	(9.02)
MSRTC	0.026	-0.040	0.022	0.025	0.006	-0.065	0.022	0.017
	(0.60)	(0.84)	(0.55)	(0.60)	(0.13)	(1.40)	(0.51)	(0.41)
KnSRTC	0.343	0.421	0.338	0.351	0.281	0.606	0.309	0.317
	(6.95)	(7.79)	(7.36)	(7.49)	(5.35)	(5.77)	(6.45)	(6.86)
NWKnRTC	0.292	0.397	0.287	0.295	0.169	0.642	0.182	0.187
	(5.55)	(7.10)	(5.84)	(5.87)	(2.97)	(4.60)	(3.23)	(3.38)
GSRTC	0.121	0.143	0.115	0.110	0.178	0.441	0.217	0.213
	(2.53)	(2.63)	(2.72)	(2.52)	(3.06)	(5.24)	(4.40)	(4.36)
UPSRTC	-0.073	-0.003	-0.086	-0.093	0.012	0.323	0.063	0.067
	(1.09)	(0.04)	(1.87)	(1.98)	(0.20)	(3.02)	(1.37)	(1.48)
RSRTC	0.171	0.202	0.162	0.173	0.225	0.589	0.267	0.280
	(2.97)	(3.09)	(3.60)	(3.77)	(3.55)	(4.56)	(4.96)	(5.60)
STHAR	0.185	0.174	0.179	0.217	0.185	0.651	0.207	0.224
	(3.49)	(2.88)	(3.73)	(4.66)	(2.81)	(4.08)	(3.25)	(3.90)

[15] t-values are given in parentheses. APSRTC is taken as reference for models from TFP1 to TFP4 whereas APSRTC (2000-01) is taken as reference for models from TFP5 to TFP8. TDs and FD*T stands for time dummies and firm dummies*time trend respectively. The parameters estimates for the time dummies and firm dummies*time trend are not reported in the table due to space limitation. Variable 'Average Fare' represents average fare at 2010-11 prices.

SBSTC	-0.138	-0.023	-0.146	-0.125	0.238	1.478	0.266	0.281
	(1.30)	(0.19)	(1.46)	(1.22)	(1.71)	(4.06)	(1.93)	(2.08)
KDTC	0.115	0.180	0.106	0.133	0.272	1.478	0.311	0.331
	(1.18)	(1.64)	(1.17)	(1.44)	(1.99)	(3.88)	(2.32)	(2.54)
OSRTC	-0.020	0.108	-0.033	-0.001	0.211	1.489	0.292	0.312
	(0.19)	(0.91)	(0.34)	(0.01)	(1.44)	(3.88)	(2.22)	(2.44)
	+FDs*T	+FDs*T	+FDs*T	+FDs*T	+TDs	+TDs	+TDs	+TDs
Number of observations	121	121	121	121	121	121	121	121
Degrees of freedom	94	95	95	96	95	96	96	97
R-square	0.979	0.972	0.979	0.977	0.953	0.942	0.952	0.952
Log-Likelihood	228.44	211.67	228.40	224.78	180.09	166.49	179.12	178.84

The residual TFP index is computed by removing the effects of uncontrollable variables (output and average fare) from the gross TFP values. These indices, normalized so that the level of residual TFP for APSRTC in 2000-01 is 1.000, are presented in Table 14 along with their compound annual growth rate. Comparing residual TFP index with the gross TFP index, it is noted that within a firm, residual TFPs have a much larger spread than gross TFP whereas, inter-firm spread is less in case of residual TFP than the gross TFP. Furthermore, growth rate of residual TFP is higher than that of gross TFP in five STUs (APSRTC, GSRTC, RSRTC, STHAR, and KDTC) whereas for the rest, growth rate of gross TFP is higher than that of residual TFP.

Table 14. Residual TFP of STUs, 2000-01 to 2010-11, Indices; APSRTC (2000-01) = 1.000

STUs	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	CAGR (%)
APSRTC	1.000	0.983	1.095	1.081	1.163	1.245	1.305	1.384	1.400	1.455	1.351	3.06
MSRTC	0.852	0.847	0.830	0.798	0.772	0.731	0.699	0.768	0.848	0.835	0.857	0.06
KnSRTC	1.351	1.543	1.481	1.644	1.567	1.463	1.433	1.521	1.397	1.335	1.413	0.45
NWKnRTC	1.423	1.438	1.451	1.447	1.488	1.331	1.168	1.211	1.111	1.157	1.252	-1.27
GSRTC	1.164	1.222	1.112	0.899	0.995	1.006	1.132	1.239	1.468	1.534	1.523	2.72
UPSRTC	0.909	0.931	0.964	1.079	1.191	1.157	1.228	1.253	1.409	1.362	1.340	3.96
RSRTC	1.113	1.156	1.226	1.299	1.445	1.419	1.414	1.492	1.512	1.572	1.600	3.70
STHAR	1.124	1.239	1.195	1.205	1.240	1.290	1.347	1.313	1.673	1.439	1.289	1.38
SBSTC	0.703	0.748	0.762	0.692	0.699	0.702	0.817	0.834	0.895	1.026	1.019	3.78
KDTC	0.779	0.870	0.895	0.924	0.838	0.897	0.823	0.826	0.783	0.823	0.899	1.44
OSRTC	0.805	0.949	1.097	1.093	1.160	1.197	1.144	1.243	1.280	1.369	1.404	5.73

In Table 15 we rank the STUs by their level and growth of residual TFP, gross TFP, and output during 2000s. In terms of both level as well as growth of residual TFP, there is a wide disparity among STUs over the period 2000-01 to 2010-11, which resulted in substantial changes in their ranking. For example, from 2000-01 to 2010-11 period RSRTC rose from 5th to 1st rank, GSRTC rose from 4th to 2nd rank, and OSRTC rose from 9th to 4th rank while NWKnRTC fell from 1st to 8th rank, MSRTC fell from 8th to 11th rank, and STHAR fell from 3rd to 7th rank. During the sample period, KnSRTC seems to be the most consistent performer. It was the 2nd most productive STU during the year 2000-01 and the 3rd most productive STU during the year 2010-11. In fact, it experienced the highest productive efficiency among the sample STUs from 2001-02 to 2007-08.

It appears that there is statistically insignificant relationship between residual TFP and size of STUs (see, Figure 2). Correlation coefficient between residual TFP and size of STUs (measured in terms of passenger-kilometers) is 0.136 with t-statistic of 1.50, which shows that the coefficient is statistically insignificant at 1% level of significance. This result shows that the productive efficiency (i.e., residual TFP) of STUs is independent of their size.

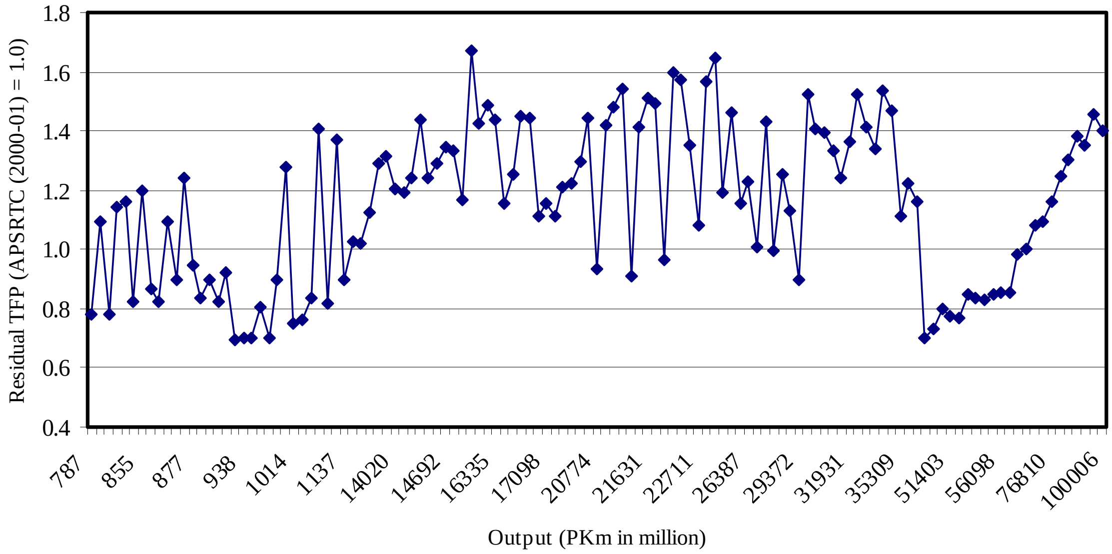
In terms of residual TFP growth, the STUs fall in four distinct categories. Five STUs, OSRTC (5.73%), UPSRTC (3.96%), SBSTC (3.78%), RSRTC (3.70%), and APSRTC (3.06%) achieved very high growth rate in their productive efficiency. Three STUs achieved moderate growth in their productive efficiency ranging from 1.38% per year (STHAR) to 2.72% per year (GSRTC). Two STUs, MSRTC (0.06%) and KnSRTC (0.45%), achieved fairly low growth whereas one STU, NWKnRTC (-1.27%) faced decline in its productive efficiency during the sample period.

A comparison of residual TFP and gross TFP shows that there is a strong positive relationship between these two indicators of productivity. Correlation coefficient between residual TFP and gross TFP is 0.954 with t-statistic of 34.61, which shows that the coefficient is statistically significant at 1% level of significance. As a result, both in the year 2000-01 and 2010-11, STUs' rank according to their residual TFP performance is somewhat similar to their rank according to their gross TFP performance. For example, during the year 2000-01, top five most productive STUs according to both residual TFP and gross TFP performance include NWKnRTC, KnSRTC, STHAR, GSRTC, and RSRTC. During the year 2010-11, except UPSRTC and OSRTC, all STUs have similar rank according to both residual TFP and gross TFP. Furthermore, RSRTC experienced 1st rank in 2010-11 and 5th rank in 2000-01 according to both measures of productivity. It is interesting to note that the sample STUs experienced perfect similarity in their rank according to growth in their residual TFP and gross TFP during the sample period. According to growth in both measures of productivity, OSRTC is ranked 1st whereas NWKnRTC is ranked the last.

Table 15. STUs ranked by 2000-01 & 2010-11 level of residual TFP and Size

STUs	Residual TFP 2000-01		Residual TFP 2010-11		Residual TFP CAGR		TFP 2000-01	TFP 2010-11	TFP CAGR	Output 2000-01	Output 2010-11	Output CAGR
	Rank	Level	Rank	Level	Rank	Level (%)	Rank	Rank	Rank	Rank	Rank	Rank
APSRTC	6	1.000	5	1.351	5	3.06	6	4	5	1	1	3
MSRTC	8	0.852	11	0.857	10	0.06	7	9	10	2	2	10
KnSRTC	2	1.351	3	1.413	9	0.45	2	2	9	4	3	2
NWKnRTC	1	1.423	8	1.252	11	-1.27	1	7	11	7	7	8
GSRTC	4	1.164	2	1.523	6	2.72	3	5	6	3	5	11
UPSRTC	7	0.909	6	1.340	2	3.96	8	3	2	5	4	1
RSRTC	5	1.113	1	1.600	4	3.70	5	1	4	6	6	5
STHAR	3	1.124	7	1.289	8	1.38	4	6	8	8	8	9
SBSTC	11	0.703	9	1.019	3	3.78	11	10	3	9	9	4
KDTC	10	0.779	10	0.899	7	1.44	9	11	7	11	11	6
OSRTC	9	0.805	4	1.404	1	5.73	10	8	1	10	10	7

Figure 2. Relationship between Residual TFP and Output of STUs during 2000s



6. The Issue of Convergence of Residual TFP

Finally, it is natural to ask whether productive efficiency ranks of the STUs differ significantly across the years. Specifically, we try to examine the temporal relationship of the cross-sectional rankings of individual STUs' productive efficiency estimates. To address this issue, we calculate Kendall's index of rank concordance (Siegel, 1956) along with coefficient of variation of residual TFP for sample period. The motivation for calculating it in this context is to determine if the STUs that were inefficient earlier are still inefficient or whether there has been any convergence.

The results are presented in Table 16. Second column of this Table reports coefficient of variation of residual TFP, CV(RTFPt), for various time, t; the convergence hypothesis, d[CV(RTFPt)]/dt < 0, is tested by regressing CV(RTFPt) on t. The estimated equation with t-statistic values in parentheses is:

$$CV(RTFP_t) = 0.245 - 0.003\,t;\; R^2 = 0.247 \qquad \textbf{(5)}$$
$$(21.75)\quad (1.72)$$

Table 16. Measures of Convergence of Productive Efficiency for STUs in India, 2000-01 to 2010-11

Year	Coefficient of Variation	Multi-annual Kendall	χ^2 test statistic for Multi-annual Kendall	Binary-Kendall	χ^2 test statistic for Binary-Kendall
2000-01	0.232	1.000		1.000	
2001-02	0.235	0.973	19.46	0.973	19.46
2002-03	0.211	0.956	28.68	0.945	18.91
2003-04	0.255	0.911	36.44	0.873	17.45
2004-05	0.256	0.908	45.40	0.918	18.36
2005-06	0.232	0.910	54.60	0.895	17.91
2006-07	0.222	0.886	62.02	0.832	16.64
2007-08	0.223	0.853	68.24	0.764	15.27

2008-09	0.238	0.797	71.73	0.768	15.36
2009-10	0.210	0.751	75.10	0.705	14.09
2010-11	0.192	0.732	80.52	0.714	14.27

Although sign of coefficient of time is negative, coefficient is statistically insignificant even at 10% level of significance. Therefore, coefficient of variation of residual TFP is not decreasing significantly over time. The third and fifth column of Table 16 reports multi-annual Kendall index and binary-Kendall index of rank concordance respectively, which are used to determine the association among the ranking obtained by various STUs in different years.[16] Kendall's indices of rank concordance are calculated as follows:

$$KI_t = \frac{Variance(\sum_{t=0}^{T} AR(RTFP)_{st})}{Variance((T+1) * AR(RTFP)_{s0})} \quad \textbf{(6)}$$

$$KIa_t = \frac{Variance(AR(RTFP)_{st} + AR(RTFP)_{s0})}{Variance(2 * AR(RTFP)_{s0})} \quad \textbf{(7)}$$

where, KI_t is multi-annual Kendall index of rank concordance; KIa_t is binary-Kendall index of rank concordance; $AR(RTFP)_{st}$ is the actual rank of STU *s*'s residual TFP level in year *t*; $AR(RTFP)_{s0}$ is the actual rank of STU *s*'s residual TFP level in the initial year 0; and *(T+1)* is the number of years for which data are used in constructing the index.

The multi-annual version of the index takes into account of the ranks for intervening years between *t* and 0 by computing the index for a moving-sum of years. This index contains all possible pairs of years for which the binary measure could be computed.

The value of rank concordance index ranges from zero to one. The denominator of the index is the maximum sum of ranks, which would be obtained if there were no change in rankings over time. The closer the index value is to zero the greater the extent of mobility within the distribution. If convergence is present the index will be less than unity. The statistic is distributed as chi-squared and we test the null hypothesis of no association between ranks of different years. The test statistic is $\chi^2 = \tau(N-1)KI$, where τ is the number of years of ranking (2 in the binary case), N is the number of STUs, and KI is the calculated Kendall's index of rank concordance. There are (N-1) degrees of freedom.

According to Multi-annual Kendall Index, the null hypothesis of no association between ranks of different years is rejected at 5% level of significance (critical $\chi^2_{0.05,10} = 18.307$). However, according to Binary-Kendall Index, the null hypothesis could not be rejected for all the years. As a result, when we compare STUs' ranks according to their productive efficiency in 2010-11 with that in 2000-01, we find that their ranks have changed significantly. But, when we compare STUs' ranks in 2004-05 with that in 2000-01, we find that their ranks haven't changed significantly. Therefore, cross-sectional dispersion of STUs' productive efficiency is diminishing over time but not significantly.

Much of the earlier empirical work concerning convergence has been based on the regression equation, $\ln P_t = \alpha + \beta \ln P_0 + u$, where P_t is productivity at time t and P_0 is productivity at time 0. The 'mean-reversion hypothesis', hypothesis that the firms with lowest initial productivity level tended to have the highest subsequent productivity growth,

[16] For a lucid discussion about Kendall's index of rank concordance, see, Singh, 2000; Jha et al., 1999; Boyle and McCarthy, 1997; and Siegel, 1956.

is tested by testing the hypothesis that $\beta<1$. It appears that at least some researchers (for example, Mankiew, Romer, and Weil (1992)) considered the mean-reversion hypothesis to be equivalent to the convergence hypothesis. Lichtenberg (1994) has successfully argued that mean-reversion is a necessary condition for convergence, but not a sufficient condition; convergence may fail to hold even if $\beta<1$. He further argued that the degree of convergence depends not only on β but also on R^2 of the above equation, i.e, on the relative importance of random disturbances in determining productivity.

For this study, mean-reversion hypothesis is tested by regressing natural logarithm of residual TFP of 2010-11 on natural logarithm of residual TFP of 2000-01. The null hypothesis of no mean-reversion is rejected according to t-test. Regression results are reported below (with t-statistic in parentheses):

$$\ln RTFP_{2010\text{-}11} = \underset{(4.12)}{0.221} + \underset{(2.16)}{0.527}\ln RTFP_{2000\text{-}01} + e; \; R^2 = 0.341, \; N = 11$$

The convergence test statistic is inversely related to β; the lower (closer to 0) is β, the greater the degree of mean-reversion is. To test the null hypothesis of no convergence, we compute the statistic R^2/β^2, which is equal to the ratio of variance of $\ln RTFP_{2000\text{-}01}$ to the variance of $\ln RTFP_{2010\text{-}11}$. This ratio follows F-distribution with N-2, N-2 degrees of freedom. In this case, $R^2/\beta^2 = 0.341/(0.527)^2 = 1.23$. Although this ratio is greater than 1, it is far from significant since critical $F_{0.05;\,9,\,9} = 3.18$. Therefore, we could not reject the null hypothesis of no convergence. This result shows that the hypotheses of convergence and mean-reversion are not equivalent. In this case of STUs' productive efficiency, null hypothesis of no mean reversion is rejected, but the null hypothesis of no convergence is not rejected.

7. Concluding Remarks

Eleven STUs are compared on the basis of their levels and growth of partial factor productivity, total factor productivity, and productive efficiency. Annual estimates have been presented for the years 2000-01 to 2010-11. We found that there is a wide disparity among STUs for all these productivity measures. It seems that there is a positive, though not very strong, relationship between total factor productivity and size of STUs. In terms of TFP growth, STUs fall in four distinct categories. Four STUs achieved very high growth rate of productivity ranging from 3.54% per year for RSRTC to 6.25% per year for OSRTC whereas one STU, NWKnRTC, faced decline in its productivity during 2000s. However, only two STUs, UPSRTC and OSRTC, could improve their economic profitability despite the fact that ten out of eleven STUs could improve their total factor productivity during the sample period. This is mainly because none of the STUs could increase their fare in line with the increase in their input factor prices.

Since total factor productivity results are based on observed productivity rather than productive efficiency, separating the effects of productive efficiency from those of network and production environment is a basic requirement for making a proper inter-firm efficiency comparison. This is done using second-stage regression analysis where TFP indices are regressed against output, average fare, passenger lead, load factor, and fleet utilization. However, the most suitable model includes only four explanatory variables (output, average fare, load factor, and fleet utilization) with both firm-specific intercept and firm-specific time trends since passenger lead is found to be statistically insignificant both according to t-statistic and log-likelihood ratio test. This model is used to compute the residual TFP indices, a measure of productive efficiency, by removing the effects of uncontrollable variables (i.e., output and average fare) from the gross TFP values. Comparing residual TFP index with the gross TFP index, it is found that within a firm, residual TFPs have a much larger spread than gross TFP whereas, inter-firm spread is less in case of residual TFP than the gross TFP. Unlike gross TFP, residual TFP and size of STUs has statistically insignificant relationship. However, there is a strong positive relationship between residual TFP and gross TFP; correlation coefficient between them is 0.954 with t-statistic of 34.61. As a result, both in the year 2000-01 and 2010-11, STUs' rank according to their residual TFP performance is somewhat similar to their rank according to their gross TFP performance. It is interesting to note that the STUs experienced perfect similarity in their rank according to growth in their residual TFP and gross TFP during 2000s. Moreover, in terms of residual TFP growth, the STUs fall in four distinct categories. Five STUs, OSRTC (5.73%), UPSRTC (3.96%), SBSTC (3.78%), RSRTC (3.70%), and APSRTC (3.06%) achieved very high growth rate whereas three STUs achieved moderate growth in their productive efficiency ranging from 1.38% per year (STHAR) to 2.72% per year (GSRTC). Two STUs, MSRTC (0.06%) and KnSRTC (0.45%), achieved fairly low growth whereas one STU, NWKnRTC (-1.27%) faced decline in its productive efficiency during the sample period.

We also examined the temporal relationship of the cross-sectional rankings of individual STUs' productive efficiency estimates. To address this issue, we calculated Kendall's index of rank concordance along with coefficient of variation of residual TFP during 2000s. Using regression analysis, we found that although the coefficient of variation of residual TFP is decreasing over time, but decrease is statistically insignificant. According to multi-annual Kendall index, the null hypothesis of no association between productive efficiency ranks is rejected. However, according to binary-Kendall index, the null hypothesis could not be rejected for all the years. In other words, cross-sectional dispersion of STUs' productive efficiency is diminishing over time but not significantly.

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