# Testing of Technical Efficiency Catching-up in Indian Sugar Industry: A Longitudinal Analysis of Sugar Producing States

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***Abstract***

The study is an endeavor to test the validity of convergence hypothesis in Indian sugar Industry. For inferential purpose, data for 12 major sugar-producing states over the period 1974/75 to 2004/05 has been used. The technical efficiency and scale efficiency scores have been computed using the technique of full cumulative data envelopment analysis (DEA). From the empirical results, an average inefficiency to the tune of 35.55 percent has been observed in Indian sugar industry. The search for sources of technical inefficiency reveals that managerial inefficiency (i.e., pure technical inefficiency) is the dominant source and scale inefficiency is relatively scant source of it. The inference of the existence of catching-up (i.e., efficiency convergence) has been found valid during the pre-reforms period, which disappears during the post-reforms period. Moreover, the reforms process has been observed adversely affected the efficiency trends and thus, failed to exert any positive impact on the efficiency of Indian sugar industry at both national and state levels.

**Resumen**

El presente estudio trata de probar la validez de la hipótesis de convergencia en la industria azucarera india, analizando datos de los doce estados más importantes dedicados a la producción de azúcar durante el período comprendido entre 1974/75 y 2004/05. Para ello, se han calculado los resultados de la eficiencia técnica y a escala usando la técnica del Análisis Envolvente de Datos (por sus siglas DEA en inglés). De los resultados empíricos se desprende una ineficiencia media del 35,55% en la industria azucarera india. La búsqueda de las causas de esa ineficiencia técnica revela que la ineficiencia a nivel de gestión (es decir, la ineficiencia técnica pura) es el factor predominante y que la ineficiencia a escala es una causa relativamente pequeña. Hallamos que la inferencia aplicada a la recuperación económica (es decir, la convergencia eficiente) ha funcionado durante el período de pre-reformas, pero no así durante el período de post-reformas. Asimismo, observamos que el proceso de reformas ha afectado de manera adversa a las pautas de eficiencia y, por tanto, no ha tenido un impacto positivo en la eficiencia de la industria azucarera india tanto a nivel nacional como regional.

*Keywords:* Technical Efficiency, Scale Efficiency, Convergence, Indian Sugar Industry.

*JEL Classification Codes:* O10, O57, R11, C02, C69, D24

## 1. Introduction

The present study has been undertaken with the primary objective to analyze the technical efficiency convergence among the 12 major sugar producing states of India. The relevance of the study stems from the fact that the development of sugar industry in India can ensures high backward and forward linkages to Indian economy given that sugar industry is: i) second largest agro-based industry in India after the cotton-textile; ii) provides direct employment to 0.5 million and indirect employment to 55 million skilled and unskilled workers (Sanyal *et al.*, 2008); iii) contributes Rs. 25 billion annually to the centre and state exchequer in the form of taxes (ISMA, 2008); iv) potential to generate 5000MW surplus power through the process of cogeneration; and v) supporting the petroleum blending program trough the production of ethanol using molasses (the byproduct of sugar). Despite of these facts, the sugar industry in India has been offended by the ignorance of policy planners and about 35 percent sugar mill in India are running either with the negative net worth or designated as sick units (Standing Committee on Food, Civil Supply and Public Distribution, 2003). Thus, given the appalling status of the health of Indian sugar industry, there is an urgent need to analyze the trends and sources of technical efficiency in the industry (see, Pandey (2007) and, Kumar and Arora (2009a) for an introductory review of Indian sugar industry).

In recent years, there has been a flurry of academic studies to assess the technical efficiency of Indian manufacturing sector (see, Arora (2010) for literature survey). However, a scant attention has been paid to analyze the sources of technical efficiency in Indian sugar industry at both aggregated and regional perspectives. Moreover, on the basis of available literature, it has been observed that there exists no published study that concentrated on the analysis of technical efficiency convergence among the different sugar producing states of India. In the growth literature, convergence is seen as a “catching-up” process, whereby the economies with lower per-capita income grow faster than the richer ones and the gap in per-capita income between the two economies reduces. However, there exists divergence, if the gap in per-capita income between two economies widens. The present study is an endeavor to apply the same concept to test the technical efficiency catching-up and check whether the sugar producing states with low initial levels of technical efficiency are growing at such a faster rate so as to overtake the efficiency growth of the benchmark states?

## 2. Testing Convergence in TE Levels: A Methodological Precise

The study involves the realization of two principal objectives. The first objective is to analyze the sources of technical efficiency in Indian sugar industry at both aggregated and regional levels. This has been accomplished using longitudinal data for 12 states over the period of 31 years (i.e., from 1974/75 to 2004/05) and applying the method of full cumulative data envelopment analysis (FCDEA). Another principal objective of this study is to test convergence in efficiency levels (i.e., catching-up hypothesis) in Indian sugar industry. Using the concept of $\beta$- and $\sigma$-convergence, we check whether the process of the learning by doings appeared in Indian sugar industry or not during the study period and two sub-periods. To identify the convergence club of sugar producing states, ADF and PP test statistics have been used.

As noted above, the objective of the present study is to find out the answer to the following questions: i) Are less efficient sugar producing states catching up to their more efficient counterparts? ii) Are less efficient sugar producing states growing faster than more efficient ones? iii) To what extent there exists a common trend towards the convergence or divergence of efficiency levels among sugar producing states of India? To explore the answer to these questions, the concept of convergence has been utilized. The term convergence as used in the literature on international comparison of economic growth refers to the catching-up phenomenon i.e., poor economies tend to grow faster than richer economies. In a cross-section context, the term has also been used to refer to the tendency of differences in per-capita income between economies to decline over time. The similar concept of convergence has been adapted to answer the aforementioned questions that are pertinent to understand the efficiency dynamics of sugar producing states of India. The concept of convergence as used in the present study refers to the tendency of two or more sugar producing states to become similar in terms of efficiency levels. Therefore, if the sugar producing states with low levels of efficiency at the beginning of the period grow more rapidly than those with high levels of efficiency then convergence occurs implying that the less efficient sugar firms are catching-up.

The empirical analysis of present study is confined to the period of 31 years from 1974/75 to 2004/05, which has been further divided into two sub-periods on the basis of changes in macroeconomic policy governing the Indian economy: i) Pre-reforms period (1974/75 to 1990/91); and ii) Post-reforms period (1991/92 to 2004/05). The source of the data is 'Annual Survey of Industries (ASI)' wing of Ministry of Statistics and Programme Implementation (MOSPI), Government of India. The firm level data is provided by MOSPI on payment basis. The ASI firm level data has been used to work out inter-state aggregates of each input output variables. The present study utilizes single output (i.e., Gross Output) and three inputs (i.e., Total Workers, Intermediate inputs and Capacity Adjusted GFC) to compute technical efficiency scores for the sugar industry of 12 major sugar-producing states of India. Barring the variable of Capacity Adjusted GFC (i.e., capital in use), the remaining input-output variables are same as defined in Kumar and Arora (2009b). However, the variable of capacity adjusted GFC (CAGFC) can be defined as:

$$CAGFC=CU\times GFC$$

Where, CU represents the capacity utilization of each state over the study period (see, Kumar and Arora (2009b) for CU levels). The adjustment of the GFC according to the CU levels is required because i) whenever, we use capital in production function, it must be adjusted for capacity utilization because "what belongs in a production function is capital in use, and not capital in place (Solow, 1957)"; ii) most of the plants and machinery are not fully utilized in Indian sugar industry because of inadequate supply of sugarcane and intervention of the government in fixing the price both for sugar and sugarcane (Subramaniyan, 1979). Therefore, given the need to estimate a *production frontier* (or *best-practice frontier*) for analyzing inter-temporal and inter-state variations in technical efficiency of Indian sugar industry, the 'capital in place' has been adjusted to 'capital in use'.

The literature on convergence mainly spells out three types of convergences: i) *σ-convergence,* ii) absolute *β-convergence*, and iii) conditional *β-convergence* [see, Barro (1991), Barro and Sala-i-Martin (1992, 1995), Sala-i-Martin (1996), Lee *et al.* (1996) and Ghosh (2008)]. In growth literature, *σ-convergence* appears when the dispersion of output across a group of states falls over time. However, in our case, *σ-convergence* deal with the reduction in the dispersion of the technical efficiency between 12 major sugar producing states over the given period of time, and requires the estimation of the following equation:

$$CV_t = \xi_0 + \xi_1 t + \varepsilon_{2t} \quad (1)$$

where $CV_t$ is the coefficient of variation of the technical efficiency scores among all the 12 sugar producing states at the given time period *t* (*t=1,2,…,T*). The negative value of slope coefficient $\xi_1$ would indicate the presence of *σ-convergence*, i.e., a decline in the coefficient of variation ($CV_t$) of technical efficiency scores over time implies a narrowing of the dispersion of efficiency levels (Soukiazis, 2000).

The concept of *β-convergence* relates to the catch-up phenomenon. Convergence of the *β*-type considers whether the improvement in efficiency exhibit a negative correlation with the initial level of efficiency. The absolute *β-convergence* is said to occur in a cross-section of sugar producing states if the inefficient states tend to improve in efficiency faster than the efficient ones. The existence of *β-convergence* can be examined empirically by estimating a cross-sectional regression of annual average growth rates of efficiency on the initial levels of efficiency. Thus, the testing for *β-convergence* involves estimation of the following regression equation:

$$G_{i,t,t-\tau} = \left[\ln\left(E_{i,t}\right) - \ln\left(E_{i,t-\tau}\right)\right] / \tau = \alpha + \beta \ln\left(E_{i,t-\tau}\right) + \varepsilon_{i,t} \quad (2)$$

where $G_{i,t,t-\tau} = \left[\ln\left(E_{i,t}\right) - \ln\left(E_{i,t-\tau}\right)\right] / \tau$ is the $i^{th}$ states average growth rate of efficiency between the periods *t* and *t- τ*, respectively. *τ* is the length of time period or total number of years over which the convergence has to be observed. If the regression coefficient on the initial level of $E_{i,t-\tau}$ bears a statistically significant negative sign, i.e., if *β*<0, then we can say that there exists absolute *β-convergence*. The negative coefficient of *β* signifies that relatively inefficient sugar producing states have higher growth rates that enable them to catch up with the efficient states. It should be observed that the equation (2) gives absolute, also denoted unconditional *β-convergence* under the assumption that all sugar producing states face homogenous regulatory environment.

Alongside the absolute *β-convergence*, we also tested the presence of conditional *β-convergence* in the efficiency levels using the following equation:

$$\Delta \ln\left(E_{i,t}\right) = \alpha_i - \frac{1}{T}\left(1 - e^{-\beta T}\right) \ln\left(E_{i,t-1}\right) + \sum_{j=1}^{k} \theta_j \ln(X^{j}_{i,t-1}) + \varepsilon_{i,t} \quad (3)$$

where $\Delta \ln\left(TE_{i,t}\right)$ represents the growth of technical efficiency during the period *t-1* and *t*, *β* is the speed of convergence, $X^{j}_{i,t-1}$ consists of $j^{th}$ control variable which might influence the steady-state level of technical efficiency. The choice of the control variables (or conditioning variables) $X^j$ depends upon economic theory, *a priori* beliefs about growth process and availability of the data (Ghosh, 2008). However, in order to use OLS in the estimation, the coefficient $-\frac{1}{T}\left(1 - e^{-\beta t}\right)$ is changed by a general coefficient $\varphi$ and the equation (3) can, thus, be rewritten in the following way:

$$\Delta \ln\left(E_{i,t}\right) = a_i + \varphi \ln\left(E_{i,t-1}\right) + \sum_{j=1}^{k} \theta_j \ln(X^{j}_{i,t-1}) + \varepsilon_{i,t} \quad (4)$$

where $a_i$ captures an unobserved individual effect which is assumed to be constant over time. In particular, the region-specific fixed effect $a_i$ determines the region´s steady state technical efficiency. The average growth rate of efficiency between *t-1* and *t* should be negatively related to the initial logarithm of the efficiency i.e., $\ln\left(E_{i,t-1}\right)$ to ensure conditional *β-convergence*. This relationship is represented by the common coefficient $\varphi$. Thus, conditional *β-convergence* holds if $\varphi < 0$ and statistically significant. However, as mentioned above, the region-specific fixed effect present over the whole sample period is captured by the term $a_i$. The speed of convergence *β* can be obtained from the following relationship between the coefficients of $\ln\left(E_{i,t-1}\right)$ in equations (3) and (4):

$$\beta = -\frac{1}{T}\ln(1 - T\varphi) \tag{5}$$

However, the half-period for the complete closure of the efficiency gap is calculated from the formula:

$$H = \ln(2)/\beta = 0.69/\beta \tag{6}$$

It is worth mentioning here that when a panel data regression of convergence is performed, the concept of convergence is somewhat different to the classical approach of convergence in cross-section regressions in the sense that it is now regarded as convergence towards the region´s own steady state technical efficiency. Consequently, as a region is closer to its own steady state than to the average steady state of a total group, the convergence coefficient is higher than in the cross-section analysis (Lopez-Rodriguez, 2008). The conditional convergence and absolute convergence hypothesis coincide only if all sugar-producing states have same steady state (Fung, 2006).

While the concepts of *σ-convergence* and *β-convergence* are related, they are not the same. A necessary condition for *σ-convergence* is the existence of *β-convergence* although *β-convergence* itself does not guarantee a reduction in the distribution dispersion (Thirtle *et al.*, 2003). In particular, *β-convergence* is a necessary, but not sufficient condition for *σ-convergence* (Sala-i-Martin, 1996a). One possible explanation illustrating this relationship is the 'cross-over' scenario or leapfrogging. For instance, initially less efficient sugar producing states may not only manage to catch up with efficient ones indicating *β-convergence*, but they may also cross-over and continue to surge ahead. The crossover scenario, thus, could cause an increase in the dispersion of technical efficiency levels.

Koski and Majumdar (2000) suggested that both *σ-convergence* and *β-convergence* should be used simultaneously for drawing inference about the presence of the catching-up phenomenon and leapfrogging phenomenon. They listed four distinct possibilities: i) both σ- and *β-convergence* occur due to which originally inefficient sugar producing states are catching-up the originally efficient (well-performing) states and moreover, their performance is improving at such a rate that states which were previously lagging, overtake the well-performing states in terms of chosen performance measure; ii) *σ-convergence* without *β-convergence* indicating that the dispersion of the distribution of performance measure decrease over time but leapfrogging or cross-over scenario is missing[1]; iii) *β-convergence* without *σ-convergence* implying catching-up may occur even if the *σ-convergence* measure indicates that the dispersion of the distribution of the performance measure has not decreased i.e., the formally poor performing states improve so much faster than the previous leaders and they overtake them; and iv) neither σ- nor *β-convergence* illustrating intra-distributional stability (i.e., no leapfrogging) and inter-distributional stability (i.e., no catching-up) across time.

However, the aforementioned classical concepts of convergence do not provide any scope for identifying the sugar producing states that can be described as following or not following a common steady-state path of technical efficiency. It is, however, important to identify the states, which are converging to or diverging from the national average steady state-path of technical efficiency. The primary objective of such an exercise is to examine convergence clubs (*ρ-convergence*). We have performed this utilizing the unit-root test for convergence under the time-series framework. Under this framework, convergence requires efficiency differentials across regions to be stationary (Bernard and Durlauf, 1995, 1996; Evans, 1998; Li and Papell, 1999; Ghosh, 2008). The convergence hypothesis has been tested by evaluating the univariate time-series properties of the differentials of efficiency of each of the 12 sugar producing states relative to the national average. Convergence of the state's efficiency to the national average level requires that its efficiency differential is stationary. A test of the null hypothesis of no convergence (i.e., non-stationarity) against the alternative of convergence (stationarity) is undertaken. The null hypothesis is:

$$H_0: X_{i,t}=[ln(E_{i,t})-ln(E_{*,t})]\sim I(1), \text{ for all } i=1,2,\ldots,12.$$

The alternative hypothesis of convergence is:

$$H_1: X_{i,t}=[ln(E_{i,t})-ln(E_{*,t})]\sim I(0), \text{ for all } i=1,2,\ldots,12.$$

where $X_{i,t}$ is logarithm of efficiency of the $i^{th}$ state ($ln(E_{i,t})$) relative to the national average of efficiency ($ln(E_{*,t})$) and, $I(1)$ and $I(0)$ are integrated of order 1 and 0, respectively (see, Baltagi (2001), Greene (2004) for the detail on unit root tests). The Augmented Dickey Fuller (ADF) (Dickey and Fuller, 1979, 1981) and Phillips and Perron (PP) (Phillips, 1987 and Phillips and Perron, 1988) methods are usually used to test for the stationarity of a time series. It is, however, argued that while the ADF method yields a liberal test and depends on the choice of augmented lags, the PP method is both conservative and more powerful, and not influenced by the choice of truncation lag parameters, particularly in a small sample (see Perron, 1988). In the present study, we applied both ADF and PP tests for testing club convergence (see, Asteriou and Hall, 2007 for details on ADF and PP test statistics).

However, the test of the efficiency convergence hypothesis requires the calculations of technical efficiency scores. In the present study, the following output-oriented CCR and BCC models, named after Charnes, Cooper and Rhodes (1978) and Banker, Charnes and Cooper (1984), have been utilized to get scalar measure of overall and pure technical efficiency[2], respectively.

$$\left.\begin{array}{l} \text{CCR Model} \\ \text{Maximize } TE^{k}_{CRS} = \theta_k \\ \text{subject to: } \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{ik} \\ \qquad \sum_{j=1}^{n} \lambda_j y_{rj} \ge \theta_k y_{rk} \\ \qquad \lambda_j \ge 0, \end{array}\right\} (7) \qquad \left.\begin{array}{l} \text{BCC Model} \\ \text{Maximize } TE^{k}_{VRS} = \mu_k \\ \text{subject to: } \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{ik} \\ \qquad \sum_{j=1}^{n} \lambda_j y_{rj} \ge \mu_k y_{rk} \\ \qquad \lambda_j \ge 0, \end{array}\right\} (8)$$

Where, $i = 1, 2, ..., m$ ; $r = 1, 2, ..., s$; and $j = 1, 2, ..., n.$ By using $TE_{CRS}$ and $TE_{VRS}$ measures, we derive a measure of scale efficiency (SE) as a ratio of $TE_{CRS}$ to $TE_{VRS}$ i.e.,

$$SE(\phi_k) = \frac{\theta_k}{\mu_k} \Big\} (9).$$

Bankers *et al.* (1984) proposed a rule that the number of observations used to project the efficient frontier should not be smaller than *3(m+s),* where *m* is the number of inputs and *s* is the number of outputs. However, in our case, 12 data points (i.e., sugar producing states) provide too few degrees of freedom when the production process is four-dimensional i.e., comprises three inputs (i.e., capacity adjusted GFC, intermediate inputs and total workers) and one output (i.e., gross output). For our four-dimension problem this suggests a number of DMUs must be greater than 12 for each cross-section. Thus, following Nighiem and Coelli (2002), the use of Full Cumulative Data Envelopment Analysis (FCDEA) method has been preferred over the contemporary frontier estimation. This method entails constructing overlapping windows of data, with each successive window retaining all the data from the previous window plus the current year's data. Thus, for period 1, the production frontier would be constructed from the most technically efficient DMUs observed in sample for period 1; for period 2 the production frontier would be constructed from the most technically efficient DMUs observed in combined sample for period 1 and period 2; and so on. For the final period, the production frontier would be constructed from the most technically efficient DMUs observed at any time during the analysis period (Helvoigt and Adams, 2008).

## 3. Empirical Results

The perusal of Table 1 provides that during the entire study period, the overall technical efficiency (OTE) score for Indian sugar industry ranges between the lowest of 43.67 percent to the highest of 73.77 percent, with an average of 64.45 percent. Thus, the level of overall technical inefficiency (OTIE)[3] in Indian sugar industry has been observed to the tune of 35.55 percent. This suggest that by adopting the best-practices, Indian sugar industry, on an average, can produce 35.55 percent more output using the same bundle of inputs. Thus, there exists a huge wastage of resources due to inefficient use of inputs in Indian sugar industry.

**Table 1: Overall Technical Efficiency Summary of Indian Sugar Industry**

| States | Entire Period (1974/75 to 2004/05) | Pre-Reforms Period (1974/75 to 1990/91) | Post-Reforms Period (1991/92 to 2004/05) | Maximum OTE | Minimum OTE | Post-Reforms Growth Rate | Kruskal Wallis Test |
|---|---|---|---|---|---|---|---|
| Andhra Pradesh | 0.6078 | 0.7211 | 0.4703 | 0.7558 | 0.3494 | -34.77 | 19.07* |
| Bihar | 0.6442 | 0.7415 | 0.5260 | 0.8189 | 0.4060 | -29.06 | 16.39* |
| Gujarat | 0.6993 | 0.7937 | 0.5847 | 1.0000 | 0.5224 | -26.33 | 20.12* |
| Haryana | 0.8286 | 0.8712 | 0.7768 | 1.0000 | 0.7341 | -10.83 | 16.07* |
| Karnataka | 0.6097 | 0.6965 | 0.5043 | 0.7742 | 0.4017 | -27.59 | 16.72* |
| Madhya Pradesh | 0.5703 | 0.7228 | 0.3850 | 0.8019 | 0.2369 | -46.73 | 20.12* |
| Maharashtra | 0.6211 | 0.7048 | 0.5195 | 0.7448 | 0.4454 | -26.30 | 16.07* |
| Orissa | 0.6508 | 0.7560 | 0.5229 | 0.8118 | 0.4196 | -30.83 | 13.92* |
| Punjab | 0.6117 | 0.6842 | 0.5236 | 0.7135 | 0.4522 | -23.47 | 13.92* |
| Rajasthan | 0.5814 | 0.7163 | 0.4177 | 0.7705 | 0.3215 | -41.68 | 21.94* |
| Tamil Nadu | 0.6938 | 0.7943 | 0.5717 | 0.8978 | 0.4872 | -28.03 | 18.72* |
| Uttar Pradesh | 0.6158 | 0.6834 | 0.5337 | 0.7421 | 0.4445 | -21.90 | 11.38* |
| **All India** | **0.6445** | **0.7405** | **0.5280** | **0.7602** | **0.4367** | **-28.69** | **19.77*** |

**Note:** * represent that the value is significant at 5 percent level of significance.

**Source:** Authors' Calculations

Indian government had initiated the economic reforms process in the year 1991 causing a significant structural shift in the governments' policy governing the Indian economy in general and industry in particular. Thus, for studying the impact of the industrial policy of 1991, the entire study period has been bifurcated into two sub-periods: i) pre-reforms period from 1974/75 to 1990/91; and ii) post-reforms period from 1991/92 to 2004/05. The analysis of Table 1 reveals that during the pre-reforms period, Indian sugar industry has found to be operating above the efficiency level of 70 percent in each year.

However, a precipitous decline has been noticed during the post-reforms period. To be specific, OTE declined from the average level of 74.05 percent in pre-reforms period to 52.80 percent in post-reforms period indicating a decline in OTE by 28.69 percent in the post-reforms period. The statistical significance of Kruskall-Wallis test (KW-Test) statistics supports the inference that the decline in OTE during the post-reforms period is serious enough and hence non-ignorable by all standards.

From Tables 1, it can also be noted that i) for the entire period of study, average OTE scores range between 0.5703 for Madhya Pradesh and 0.8286 for Haryana. This indicates that sugar firms in Haryana (Madhya Pradesh) are relatively more efficient (inefficient) than the firms operating in other states; ii) at the ladder of efficiency, 2nd and 3rd positions are occupied by the states of Gujarat and Tamil Nadu with average OTE scores of 0.6993 and 0.6938, respectively; iii) it is interesting to note that the states of Maharashtra and Uttar Pradesh which are popularly known as sugar bowls of India positioned almost at the middle of the efficiency ladder with average OTE scores of 0.6211 and 0.6158, respectively and thus, ranked at 6th and 7th places; iv). The comparative analysis of average OTE between two distinct regulatory phases provides that average OTE has declined in all sugar producing states during the post-reforms period relative to what has been observed during the pre-reforms period.

The statistical significance of the Kruskal-Wallis *H-Statistics* (KW-Test) also supports the inference regarding the significant decline in OTE during the post-reforms period; v) barring the case of Haryana, where average OTE has declined by about 10.83 percent in the post-reforms period, it has declined by over and above 20 percent in the remaining 11 states; and vi) the decline in OTE during the post-reforms period is more pronounced in the sugar producing states of Madhya Pradesh (46.73 percent), Rajasthan (41.68 percent), Andhra Pradesh (34.77) and Orissa (30.83).

In sum, it can be concluded that there exists substantial inter-state variations in OTE of Indian sugar industry and the reforms process has imparted a significant negative impact on it. On the whole, the analysis reveals the existence of soaring amount of overall technical inefficiency (OTIE) in the sugar industry of India in general and sugar industry of 12 major sugar producing states in particular. Thus, the empirics entail to analyze the causes for such a high level of OTIE in the sugar industry of India and its sugar producing states.

### *3.1 Sources of Technical (In)efficiency*

To know exactly the causes of OTIE in Indian sugar industry, the measure of OTE has been decomposed into two non-additive and mutually exclusive components namely, pure technical efficiency (PTE) and scale efficiency (SE). It is significant to note that in contrast to OTE measure, the PTE measure is devoid of scale effect. Therefore, all inefficiency reflected from PTE score directly results from managerial sub-performance. Keeping aside the scale effect, the PTE score reflects a sort of managerial efficiency i.e., the ability of management to convert the resources into output(s) and thus, can be treated as an index of managerial quality.

On the other hand, the SE measure indicates whether the sugar producing state in question is operating at most productive scale size (MPSS) or not? The PTE scores have been obtained by running the BCC model to estimate cumulative frontier for each sugar producing state separately.

Table 2 provides inter-state variations in the pure technical efficiency (PTE) of Indian sugar industry. It has been noted that in each year, average PTE in Indian sugar industry is to the tune of 69.25 percent per annum. This implies that 30.75 percentage points of 35.55 percent of average OTIE is due to inappropriate management practices that are being adopted by the managers in organizing input resources in the production process. However, the remaining part of the OTIE in Indian sugar industry is due to its operating at non-optimal scale size. The results thus, indicate that PTIE is a dominant source and scale inefficiency (SIE) is relatively a meager source of overall technical inefficiency (OTIE) in Indian sugar industry.

The decomposition of OTE into two aforementioned components for the two distinct sub-periods delineates a precipitous decline of PTE by 26.17 percent during the post-reforms period. An average PTE of 0.5798 for the post-reforms period in comparison of 0.7854 during the pre-reforms period confirms this fact. The results of Kruskal-Wallis test (KW-Test) provide that the observed decline in average PTE in Indian sugar industry is significant in statistical sense. The direct connotation of this result is that the reforms process has worsen the managerial efficiency of the Indian sugar industry. In addition, PTIE found to be contributing about 90 percent of OTIE in comparison of 83 percent during the pre-reforms period[4].

| Table 2: Pure Technical Efficiency Summary of Indian Sugar Industry | | | | | | | |
|---|---|---|---|---|---|---|---|
| **States** | **Entire Period (1974/75 to 2004/05)** | **Pre-Reforms Period (1974/75 to 1990/91)** | **Post-Reforms Period (1991/92 to 2004/05)** | **Maximum PTE** | **Minimum PTE** | **Post-Reforms Growth Rate** | **Kruskal Wallis Test** |
| Andhra Pradesh | 0.6206 | 0.7318 | 0.4855 | 0.7610 | 0.3710 | -33.67 | 16.39* |
| Bihar | 0.6602 | 0.7504 | 0.5507 | 0.8198 | 0.4392 | -26.62 | 14.83* |
| Gujarat | 0.7447 | 0.8241 | 0.6482 | 1.0000 | 0.5805 | -21.35 | 19.77* |
| Haryana | 0.8490 | 0.8987 | 0.7886 | 1.0000 | 0.7478 | -12.24 | 21.20* |
| Karnataka | 0.6659 | 0.7631 | 0.5480 | 0.8341 | 0.4556 | -28.19 | 18.38* |
| Madhya Pradesh | 0.5915 | 0.7353 | 0.4169 | 0.8080 | 0.2555 | -43.30 | 20.12* |
| Maharashtra | 0.7097 | 0.8082 | 0.5901 | 0.9016 | 0.5196 | -26.99 | 20.84* |
| Orissa | 0.8317 | 0.9167 | 0.7285 | 1.0000 | 0.6464 | -20.53 | 16.72* |
| Punjab | 0.6269 | 0.6994 | 0.5389 | 0.7354 | 0.4615 | -22.95 | 13.63* |
| Rajasthan | 0.6111 | 0.7254 | 0.4723 | 0.7875 | 0.3421 | -34.90 | 21.20* |
| Tamil Nadu | 0.7470 | 0.8420 | 0.6315 | 0.9909 | 0.5511 | -25.00 | 17.04* |
| Uttar Pradesh | 0.6521 | 0.7292 | 0.5585 | 0.7745 | 0.4574 | -23.41 | 13.63* |
| **All India** | **0.6925** | **0.7854** | **0.5798** | **0.8133** | **0.4927** | **-26.17** | **20.48*** |
| **Note:** * represent that the value is significant at 5 percent level of significance. | | | | | | | |
| **Source:** Authors' Calculations | | | | | | | |

The inter-state analysis reveals that barring the sugar industry of Orissa, PTIE dominates SIE in the remaining 11 sugar producing states. However, in Orissa, about 48 percent of OTIE is contributed by PTIE and the rest is contributed by SIE. The analysis regarding the impact of economic reforms on OTE components reveals that all the sugar-producing states have experienced a decline in managerial efficiency (i.e., PTE) during the post-reforms period. The highest decline has been observed in Madhya Pradesh (i.e., by 43.30 percent) followed by Rajasthan (i.e., 34.90 percent) and Andhra Pradesh (i.e., by 33.67 percent). Moreover, barring the state of Haryana, the sugar industry in the remaining 8 states observed a decline in average PTE between 20 and 30 percent. Thus, the problem of inapt managerial practices has become more critical during the post-reforms period.

As noted above, a ratio of OTE scores to PTE scores gives SE score and given SE<1 implies that in the representative sugar producing state under evaluation, a portion of OTIE is explained by the scale inefficiency (SIE). The analysis of Table 3 provides that the level of scale efficiency is above 90 percent in the sugar industry of All-India and its 12 major sugar producing states during the entire study period and two sub-periods. Regarding the impact of economic reforms, barring the state of Haryana, all other states have experienced a decline in SE during the post-reforms period in comparison of the pre-reforms period. Further, except Karnataka, Maharashtra and Punjab, decline in SE for remaining 8 states is statistically significant (see Kruskal-Wallis test statistics).

**Table 3: Scale Efficiency Summary of Indian Sugar Industry**

| States | Entire Period (1974/75 to 2004/05) | Pre-Reforms Period (1974/75 to 1990/91) | Post-Reforms Period (1991/92 to 2004/05) | Maximum SE | Minimum SE | Post-Reforms Growth Rate | Kruskal Wallis Test |
|---|---|---|---|---|---|---|---|
| Andhra Pradesh | 0.9686 | 0.9848 | 0.9490 | 0.9979 | 0.9173 | -3.64 | 12.20* |
| Bihar | 0.9697 | 0.9880 | 0.9474 | 0.9994 | 0.9159 | -4.1 | 14.22* |
| Gujarat | 0.9382 | 0.9608 | 0.9107 | 1.0000 | 0.8813 | -5.22 | 18.72* |
| Haryana | 0.9750 | 0.9688 | 0.9826 | 1.0000 | 0.9523 | 1.43 | 10.08* |
| Karnataka | 0.9064 | 0.9122 | 0.8993 | 0.9504 | 0.8298 | -1.41 | 3.63 |
| Madhya Pradesh | 0.9634 | 0.9823 | 0.9405 | 0.9993 | 0.8825 | -4.25 | 10.86* |
| Maharashtra | 0.8750 | 0.8741 | 0.8760 | 0.9449 | 0.7223 | 0.21 | 1.42 |
| Orissa | 0.7980 | 0.8346 | 0.7536 | 0.9451 | 0.6527 | -9.70 | 8.17* |
| Punjab | 0.9782 | 0.9785 | 0.9778 | 0.9959 | 0.9549 | -0.07 | 0.91 |
| Rajasthan | 0.9559 | 0.9869 | 0.9183 | 0.9951 | 0.5641 | -6.95 | 12.20* |
| Tamil Nadu | 0.9220 | 0.9431 | 0.8965 | 0.9674 | 0.8471 | -4.94 | 15.44* |
| Uttar Pradesh | 0.9531 | 0.9364 | 0.9732 | 0.9850 | 0.8322 | 3.93 | 14.83* |
| **All India** | **0.9336** | **0.9459** | **0.9187** | **0.9648** | **0.8960** | **-2.87** | **10.34*** |

**Note:** * represent that the value is significant at 5 percent level of significance.

**Source:** Authors' Calculations

### *3.2 Catching-Up or Convergence in Indian Sugar Industry*

Table 4 provides the results pertaining to *β-convergence*. A negative but statistically insignificant slope coefficient -0.019 for OTE indicate that the process of catching-up in overall efficiency levels among the 12 sugar producing states is weak. However, a comparison of distinct sub-periods reveals that i) efficiency levels were converging among the states at a significant rate of 5.6 percent per annum during the pre-reforms period; and ii) a significant divergence has occurred at a rate of 8.2 percent per annum during the post-reforms period. Regarding the convergence in PTE levels, it has been noted that i) during the entire study period, PTE levels have significantly converged at the rate of 1.5 percent per annum; and ii) a weak convergence phenomenon has been observed in the post-reforms period relative to a strong one in the pre-reforms period. This is evident from the fact that PTE levels have converged at an insignificant rate of 2.3 percent per annum during the post-reforms period in comparison of a significant rate of 4 percent per annum during the pre-reforms period. The pattern of convergence in SE levels has been observed to be identical of that noted in PTE levels.

**Table 4: Absolute *β-Convergence* in Indian Sugar Industry**

| Period | OTE | | PTE | | SE | |
|---|---|---|---|---|---|---|
| | ***A*** | ***β*** | ***A*** | ***β*** | ***α*** | ***B*** |
| **Entire** | -0.007* | -0.019 | -0.005* | -0.015* | -0.002 | -0.030* |
| | (0.002) | (0.100) | (0.000) | (0.018) | (0.097) | (0.030) |
| **Pre-Reforms** | -0.007* | -0.050* | -0.005* | -0.040* | -0.001* | -0.046* |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.004) | (0.000) |
| **Post-Reforms** | -0.0001 | 0.082 | -0.009* | -0.023 | -0.004 | -0.080 |
| | (0.990) | (0.190) | (0.042) | (0.521) | (0.179) | (0.435) |

**Notes:** i) * signify that coefficient is significant at 5 percent level of significant; ii) Figures in parenthesis of type ( ) are *p-values*.

**Source:** Authors' Calculations

However, the test of conditional *β-convergence* using panel data models requires the introduction of either cross-sectional, time specific or both types of the effects in the model. Fisher's specification test has been applied to ascertain the significance of cross-sectional or time specific effects. Table 5 provides the Fishers' *F*- and $\chi^2$-statistics to test the null hypothesis of the insignificant cross-sectional, time specific and a combination of both effects. The analysis provides that cross-sectional (i.e., states specific) effects are statistically insignificant whereas time specific effects are significant and must be included while estimating model (3) using panel data regression techniques.

| **Table 5: Fisher's Specification Test for Including Cross-Sectional or Time Specific Effects in Panel-data Estimation of Conditional *β-Convergence*** | | | | | | |
|---|---|---|---|---|---|---|
| **Measure of Technical Efficiency** | **Null-Hypothesis** | | | | | |
| | **Significance of Cross-Sectional Effect** | | **Significance of Period Effect** | | **Significance of both Cross-Sectional and Period Effect** | |
| | **F-test** | **$\chi^2$-test** | **F-test** | **$\chi^2$-test** | **F-test** | **$\chi^2$-test** |
| OTE | 1.344 | 16.561 | 15.121* | 314.648* | 11.777* | 329.903* |
| | (0.199) | (0.122) | (0.000) | (0.000) | (0.000) | (0.000) |
| PTE | 1.448 | 17.813 | 16.722* | 336.196* | 12.786* | 347.952* |
| | (0.150) | (0.086) | (0.000) | (0.000) | (0.000) | (0.000) |
| SE | 1.160 | 14.343 | 1.798* | 55.306* | 1.753* | 72.551* |
| | (0.314) | (0.215) | (0.008) | (0.002) | (0.005) | (0.001) |
| **Notes:** i) * signify that coefficient is significant at 5 percent level of significant; ii) Figures in parenthesis of type ( ) are *p-values*. | | | | | | |
| **Source:** Authors' Calculations | | | | | | |

Table 6 gives the estimates of model (3) and also reports the speed of convergence in Indian sugar industry. The Hausman $\chi^2$-statistics has been used to test the null hypothesis of insignificant correlation between $X_{it}$ and $e_{it}$. Testing of the significance of correlation between $X_{it}$ and $e_{it}$ helps to check the suitability of random effect or fixed effect model to estimate a given panel data regression model. If the null hypothesis is rejected then we can say that fixed effect is a better choice. However, if null is not rejected then random effect is most suitable. It has been observed that during the post-reforms period, the Hausman $\chi^2$-statistics is significant for the models estimated using all the three measures of efficiency, while during the pre-reforms period a significant statistics has been observed for the PTE convergence.

Thus, the fixed effect estimates have been reported where the Hausman $\chi^2$-statistics is significant and random effect estimates have been reported where it is insignificant.

| **Table 6: Conditional *β-Convergence* in Indian Sugar Industry** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable [Parameter]** | **OTE** | | | **PTE** | | | **SE** | | |
| | **Entire Period** | **Pre-Reforms** | **Post-Reforms** | **Entire Period** | **Pre-Reforms** | **Post-Reforms** | **Entire Period** | **Pre-Reforms** | **Post-Reforms** |
| *Constant [$a_i$]* | -0.190 | -0.062 | -0.691* | -0.087 | -0.063 | -0.271 | -0.010 | 0.065 | -0.150 |
| | (0.089) | (0.305) | (0.015) | (0.371) | (0.280) | (0.291) | (0.983) | (0.146) | (0.261) |
| *$TE_{i,t-1}$ [φ]* | -0.089* | -0.189* | -0.066 | -0.069* | -0.117* | -0.057 | -0.101* | -0.162* | -0.032 |
| | (0.000) | (0.000) | (0.095) | (0.002) | (0.000) | (0.126) | (0.000) | (0.000) | (0.558) |
| *SKILL [$\theta_1$]* | -0.025 | 0.003 | -0.049 | -0.022 | -0.018 | -0.029 | 0.010 | 0.017* | 0.015 |
| | (0.137) | (0.769) | (0.128) | (0.173) | (0.107) | (0.350) | (0.264) | (0.044) | (0.370) |
| *RETURN [$\theta_2$]* | 0.002 | 0.005 | 0.010 | 0.001 | 0.006 | 0.003 | -0.002 | -0.006 | 0.002 |
| | (0.886) | (0.392) | (0.669) | (0.962) | (0.353) | (0.878) | (0.718) | (0.180) | (0.880) |
| *K/L [$\theta_3$]* | -0.009 | -0.019* | 0.021 | -0.002 | -0.010* | 0.011 | -0.010* | -0.007 | -0.002 |
| | (0.244) | (0.000) | (0.263) | (0.749) | (0.025) | (0.497) | (0.009) | (0.054) | (0.794) |
| *CUDEA [$\theta_4$]* | 0.002 | -0.003 | -0.001 | -0.0004 | 0.007 | -0.004 | 0.003 | -0.006 | 0.002 |
| | (0.861) | (0.620) | (0.942) | (0.964) | (0.309) | (0.813) | (0.584) | (0.265) | (0.841) |
| *RMATERIAL* | 0.012 | 0.011* | 0.017 | 0.003 | 0.006 | 0.002 | 0.008* | 0.002 | 0.011* |
| *[$\theta_5$]* | (0.070) | (0.008) | (0.174) | (0.625) | (0.136) | (0.827) | (0.015) | (0.490) | (0.035) |
| **Hausman** | **7.009** | **2.737** | **51.280*** | **6.904** | **16.695*** | **43.190*** | **9.253** | **0.382** | **15.418*** |
| **[$\chi^2$-*Statitics*]** | **(0.320)** | **(0.841)** | **(0.000)** | **(0.330)** | **(0.011)** | **(0.000)** | **(0.160)** | **(0.999)** | **(0.017)** |
| **Convergence Speed [β]** | **4.271** | **8.460** | **4.674** | **3.690** | **6.441** | **4.191** | **0.871** | **7.781** | **2.644** |
| ***Half Period* [*H*]** | **16.16** | **8.16** | **14.76** | **18.70** | **10.71** | **16.46** | **79.22** | **8.87** | **26.10** |
| **$R^2$ [%$^{tage}$]** | **61.14** | **54.02** | **62.85** | **62.92** | **34.52** | **65.06** | **23.46** | **42.37** | **20.09** |
| ***DW-Statistics*** | **1.740** | **1.640** | **1.901** | **1.856** | **1.927** | **1.970** | **1.275** | **1.730** | **1.276** |

**Notes:** i) * signify that coefficient is significant at 5 percent level of significant; ii) Figures in parenthesis of type ( ) are *p-values*; and iii) The models for which Hausman statistics is significant, the null hypothesis of insignificant correlation between $X_{it}$ and $e_{it}$ is rejected and we say fixed effect is a better choice in comparison of random effect.

**Source:** Authors' Calculations

The evidences regarding the existence of efficiency catch-up are same as provided by the absolute *β-convergence*. Here also, convergence parameter is negative and statistically significant during entire and pre-reforms study period. However, for the post-reforms period the convergence has become statistically insignificant. It has been found that at the given speed of OTE convergence (i.e., 4.271 percent per annum), it will take about 16 years to cover up half of the efficiency gap towards the steady state efficiency level. The half of the managerial gap (i.e., PTE) will be removed in about 19 years with the speed of convergence 3.690 percent per annum. However, scale efficiency will take about 79 years to converge half of the steady state efficiency gap with a remarkably slow speed of convergence at the rate of 0.871 percent per annum. Such a slow SE convergence supports the argument that capacity expansion is not possible in short period and requires a long period to abolish the installed capacity gap between the sugar industries of different state. The speed of convergence has also been found to be slower down during the post-reforms period and thus, reiterate our earlier finding about the sluggishness in the catching-up process. If such a trend will continue, the inter-state difference of efficiency will continue and may increase in the future.

The results pertaining *σ-convergence* have been provided in Table 7. For the regression equations of OTE and SE measures the slope coefficients have been observed to be positive and statistically insignificant during the entire study period. However, for PTE, a significant divergence has been observed. Further, these coefficients have been found to be negative and significant in regression equations estimated for the pre-reforms period, but observed to be positive and statistically significant during the post-reforms period.

**Table 7: *σ-Convergence* in Indian Sugar Industry**

| **Period** | **OTE** | | **PTE** | | **SE** | |
|---|---|---|---|---|---|---|
| | $\xi_0$ | $\xi_1$ | $\xi_0$ | $\xi_1$ | $\xi_0$ | $\xi_1$ |
| Entire | 4.417* | 0.613 | 6.774 | 0.485* | 5.550* | 0.064 |
| | (0.002) | (0.100) | (0.006) | (0.001) | (0.000) | (0.280) |
| Pre-Reforms | 14.420* | -0.655* | 14.522* | -0.532* | 9.875* | -0.475* |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post-Reforms | 11.797* | 1.249* | 15.192* | 0.687 | 4.574* | 0.423* |
| | (0.000) | (0.009) | (0.002) | (0.142) | (0.000) | (0.002) |

**Notes**: i) * signify that coefficient is significant at 5 percent level of significant; ii) Figures in parenthesis of type ( ) are *p-values*.

**Source:** Authors' Calculations

Thus, the results rule out the reduction in the dispersion of efficiency levels between the 12 major sugar-producing states of India. Taking the results of *β*- and *σ-convergence* together, we can say that the convergence in efficiency levels among major sugar producing states has appeared in the pre-reforms years but no significant catching-up has taken place in the period of deregulation and liberalization.

Table 8 shows that the efficiency differentials among the state's efficiency and national average of efficiency are stationary and integrated of order zero. Thus, the evidence regarding the *ρ-convergence* states that leaving the sugar industries of Uttar Pradesh and Rajasthan, the remaining 10 states together form the "convergence club" during entire study period. However, mixed evidences have been observed for the state of Uttar-Pradesh and Rajasthan. The ADF-test is unable to reject the null of non-stationary OTE differentials for the state of Uttar-Pradesh. However, the SE differentials are found to be non-stationary using the ADF-statistics for the state of Rajasthan. Further, the PP-test also supports the inclusion of these states in convergence club at 5 percent level of significance.

Thus, all the states are found to be converging towards the national average with negative and significant $Z(\hat{\rho})$ at the 5 percent levels of significance during the entire study period.

However, the story differs while comparing the existence of *ρ-convergence* during the post-reforms period in comparison to the pre-reforms period. To check the presence of unit-root in the 'differentials among the state's efficiency and national average of efficiency ($Y_t$)' during two sub-periods, the ADF test equation can be slightly modified as:

$$\Delta Y_t = \rho Y_{t-1} + \lambda\left(D_{t-1}Y_{t-1}\right) + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + u_t \qquad (10)$$

Where, $D_{t-1} = \begin{cases} 0: \text{Pre- Reforms Period} \\ 1: \text{Post- Reforms Period} \end{cases}$

The inference about the presence of convergence during pre-reforms period will be drawn using $Z(\hat{\rho})$ statistics. However, during post-reforms period, the coefficient $\hat{\rho}$ will be inflated by the addition of $\hat{\lambda}$ and the statistics $Z(\hat{\rho})$ can be computed as:

$$Z(\hat{\rho}) = \frac{\hat{\rho} + \hat{\lambda}}{S.E.(\hat{\rho} + \hat{\lambda})} = \frac{\hat{\rho} + \hat{\lambda}}{\sqrt{Var(\hat{\rho}) + Var(\hat{\lambda}) + 2Cov(\hat{\rho}\hat{\lambda})}}$$

**Table 8: Club-Convergence in Indian Sugar Industry-An Application of Augmented Dickey Fuller and Phillip-Perron Unit Root Test**

| States | OTE | | PTE | | SE | |
|---|---|---|---|---|---|---|
| | ADF | PP | ADF | PP | ADF | PP |
| **Entire Period** | | | | | | |
| Andhra Pradesh | -30.27* | -22.40* | -30.34* | -19.39* | -72.52* | -50.48* |
| Bihar | -94.65* | -66.23* | -71.63* | -50.39* | -263.09* | -204.78* |
| Gujarat | -88.73* | -54.90* | -86.88* | -51.43* | -375.33* | -303.88* |
| Haryana | -70.17* | -38.89* | -78.57* | -44.60* | -255.49* | -147.56* |
| Karnataka | -214.45* | -177.62* | -174.31* | -124.65* | -339.55* | -223.03* |
| Madhya Pradesh | -72.10* | -44.56* | -56.01* | -34.28* | -715.60* | -455.74* |
| Maharashtra | -282.95* | -282.95* | -175.66* | -116.56* | -276.26* | -190.07* |
| Orissa | -272.28* | -160.17* | -128.96* | -84.89* | -214.80* | -124.36* |
| Punjab | -624.91* | -467.89* | -4.35* | -734.86* | -750.90* | -491.65* |
| Rajasthan | -301.10* | -206.42* | -160.64* | -135.13* | 1.783 | -203.89* |
| Tamil Nadu | -489.76* | -409.72* | -636.24* | -540.10* | -640.27* | -440.44* |
| Uttar Pradesh | -0.193 | -467.10* | -321.87* | -875.38* | -1324.56* | -1097.99* |
| **Pre-Reforms Period** | | | | | | |
| Andhra Pradesh | -25.38* | -21.31* | -35.45* | -14.24* | -64.23* | -28.91* |
| Bihar | -75.54* | -55.65* | -69.10* | -25.36* | -198.12* | -124.58* |
| Gujarat | -60.94* | -63.12* | -75.15* | -46.41* | -245.60* | -254.47* |
| Haryana | -50.12* | -34.54* | -46.34* | -26.22* | -214.83* | -103.52* |
| Karnataka | -150.48* | -151.20* | -123.28* | -103.98* | -254.91* | -120.89* |
| Madhya Pradesh | -52.45* | -40.41* | -41.21* | -20.33* | -544.71* | -394.11* |
| Maharashtra | -180.14* | -199.23* | -150.12* | -107.21* | -201.12* | -179.54* |
| Orissa | -180.96* | -141.80* | -101.23* | -75.54* | -120.40* | -103.61* |
| Punjab | -245.54* | -348.45* | -3.36* | -434.25* | -540.65* | -425.14* |
| Rajasthan | -195.27* | -125.45* | -120.78* | -121.21* | 0.289 | -175.54* |
| Tamil Nadu | -284.12* | -245.36* | -504.25* | -420.48* | -521.97* | -398.45* |
| Uttar Pradesh | -24.44* | -311.58* | -205.46* | -720.36* | -845.44* | -745.37* |
| **Post-Reforms Period** | | | | | | |
| Andhra Pradesh | 3.21 | 3.49 | -0.98 | 1.28 | 1.89 | 2.64 |
| Bihar | -0.26 | 0.55 | -1.24 | -0.58 | 1.86 | 3.57 |
| Gujarat | 1.47 | 0.84 | -0.691 | 1.01 | -0.92 | -1.35* |
| Haryana | -0.85* | 2.69 | -0.49 | -0.14 | 2.54 | 4.68 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Karnataka*** | ***-19.46**** | ***-14.12**** | ***-20.59**** | ***-15.09**** | ***-12.87*** | ***-20.45**** |
| Madhya Pradesh | -1.38 | 0.98 | 5.44. | 7.26 | 0.86 | 1.35 |
| ***Maharashtra*** | ***-121.77**** | ***-98.94**** | ***-124.19**** | ***-101.61**** | ***-97.16**** | ***-104.48**** |
| Orissa | -0.10 | 1.84 | -1.04 | 0.85 | 4.69 | 6.18 |
| Punjab | 15.41 | 20.12 | 1.29 | 5.69 | 2.98 | 6.58 |
| Rajasthan | 17.9 | 19.87 | 10.22 | 25.14 | 0.36 | 1.45 |
| ***Tamil Nadu*** | ***-84.15**** | ***-50.29**** | ***-54.91**** | ***-42.68**** | ***-10.87**** | ***-16.14**** |
| ***Uttar Pradesh*** | ***-21.59*** | ***-15.54**** | ***--26.01**** | ***-46.85**** | ***-44.12**** | ***-49.08**** |
| **Notes:** i) * signify that coefficient is significant at 5 percent level of significant; ii) Figures in parenthesis of type ( ) are *p-values*; and iii) States in ***Bold & Italics*** format are forming convergence club during post-reforms period. | | | | | | |
| **Source:** Authors' Calculations | | | | | | |

Similarly, the equations of PP-test statistics can also be modified adding slope dummy term $\lambda\left(D_{t-1}Y_{t-1}\right)$. Table 8 also provides $Z(\hat{\rho})$ for both of sub-periods and supports the aforementioned inference of adverse impact of economic reforms on the catching-up process among major sugar producing states of India. It has been observed that during the post-reforms period, only four states namely, Maharashtra, Tamil Nadu, Uttar-Pradesh and Karnataka are forming convergence club, whereas the remaining 8 states found to be excluded from it. The exclusion of eight sugar producing states from the convergence club is thus, a major reason behind the rejection of Catching-up hypothesis during the post-reforms period in Indian sugar industry at aggregated levels.

## 4. Conclusions and Relevant Policy Implications

It has been observed that on an average, sugar industry of India is operating with a high level of OTIE, which is about 35.55 percent. It indicates that on an average 35.55 percent more output can be produced in the Indian sugar industry using the same bundle of inputs. Further, it has been observed that the dominant source of OTIE is managerial inefficiency and scale inefficiency is relatively less dominating. Moreover, there exists notable variation in the OTE ranging between 43.67 percent and 73.77 percent. It is worth mentioning here that the dominance of managerial inefficiency (i.e., PTIE) as a source of OTIE is pervasive phenomenon and not limited to a particular state. In sum, in each sugar producing state, the managerial inability in organizing the inputs is the main cause of overall technical inefficiency. From the comparative analysis of efficiency measures between pre- and post-reforms period, it has been observed that the economic reforms process has failed to exert any positive impact on the efficiency of Indian sugar industry at both national and state levels. This is evident from the fact that average efficiency of the sugar industry has observed a decline in the post-reforms period relative to pre-reforms period.

Regarding the test of technical efficiency convergence hypothesis, the presence of catching-up has been noticed during the pre-reforms period. However, the phenomenon of convergence, which was present in pre-reforms years, has been found completely disappeared from the scene during the post-reforms period. The search for the causes of the absence of catching-up among sugar producing states during post reforms-period using the technique of club-convergence delineates that only four states are forming convergence club and the remaining eight states have been excluded from it. Thus, the dominance of the number of non-converging states has led to reject the convergence hypothesis in Indian sugar industry.

On the whole, the empirical analysis presents high levels of managerial inefficiency in sugar firms operating in India. This managerial inefficiency arises due to the excessive government interventions starting right from the procurement of sugarcane to the distribution of sugar in the market (Sanyal *et al*., 2008). Sugar is highly politicized commodity covered under the Indian Essential Commodity Act, 1955. It has also been controlled by Sugarcane Control Order, 1966 (SCO, 1966) and the relevant acts of state governments (Arora, 2010; pp 6).  The discrepancies in the state level politics regarding the sugar production and distributions distort the path of efficiency convergence among sugar producing states. The absence of centralized sugar policy in India is therefore, responsible for the absence of technical efficiency catching-up in Indian sugar industry. In sum, any centralized policy to uplift sugar producing standers may uplift the technical efficiency status of Indian sugar producing firms and improve the speed of efficiency convergence among the sugar producing states of India.

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**ENDNOTES**

[1] This possibility is unlikely to happen as *β-convergence* is a necessary condition for *σ-convergence* and we cannot observe *σ-convergence* without *β-convergence*.

[2] Given the small sample size in the present study, CCR model provides better discrimination than any other DEA model especially BCC model, named after Banker, Charnes and Cooper (1984). In the CCR-model, it is assumed that constant returns to scale (CRS) prevails in the industry.

[3] OTIE=1-OTE.

[4] The contribution has been obtained by (PTIE/OTIE)×100.