

### **III. METHODOLOGY**

The methodology relating to the current study on “**Analysis of Manufacturing Sector in the Southern states of India Before and After Economic Reforms**” is discussed under the following heads:

- A. Selection of the topic
- B. Selection of the area
- C. Data base of the study
- D. Theoretical background
- E. Tools of analysis
- F. Concepts and definitions used
- G. Limitations of the study

#### **A. Selection of the topic**

Industrial sector plays a vital role in the development of Indian economy because they can solve the problems of general poverty, unemployment, backwardness, low production, low productivity and low standard of living. The Indian Government had undertaken policy reforms since 1980, but the most radical reforms have occurred since 1991, after the severe economic crisis in fiscal year 1990-91. These reforms mainly aimed at enhancing the efficiency and international competitiveness in Indian industry. After nearly more than two decades of reforms, a question that has engaged the attention of the economists in recent times is what has been the effect of these economic reforms measures on the performance of industrial sector in the post reform period in India. To know the answer, the present study attempts to present the industrial development of India in pre reform and post reform period, with particular reference to southern states of India and investigate the impact of economic reforms on industrial sector in these states, since the economy of southern states plays a significant role in achieving higher GSDP growth rate of the country.

#### **B. Selection of the area**

The four southern states namely Andhra Pradesh, Karnataka, Kerala and Tamil Nadu contribute over 24 percent of GSDP of the country. They are emerging as the major

destinations for industrialization. Further the southern states are galloping much ahead of the poorest but populous northern states with higher economic growth rates.

The industrial sector of Andhra Pradesh includes some of the key sectors like pharmacy, automobile, textiles, bio-technology, information technology, business management, pharmaceuticals, construction and real estate. According to 2011 census report, Andhra Pradesh's GSDP for 2011 was approximately ₹5,67,636 crores, placing it second among the states. The state ranks second in terms of overall Gross State Domestic Product among all the states of the Indian Union. In terms of per capita GSDP the state compares very favourable to other large states.

The state of Karnataka is best known for its software industry and now bio-technology and the state has recorded the highest growth rate in terms of GSDP and per capita GSDP in the last decade compared to other states. In the last decade, Karnataka surpassed all other states in India, pushing Karnataka's per capita income in Indian Rupees to sixth place. Karnataka is the manufacturing hub, for some of the largest public sector industries in India. The contribution of industrial sector to Karnataka's GSDP in 2010-11 census report has been 28.48 percent. The sectoral composition of Karnataka GSDP is comparable with sectoral composition of India's GSDP as 27.9 percent. The state evolved as the manufacturing hub for some of the largest public sector industries of India after independence. The major industrial sectors of Karnataka includes Aeronautics, Aerospace laboratories, heavy electrical and electronics, telephone industries machine tools, motor cycles, sugar factories, edible oil processing, pharmaceutical factors, textile processing units, steel producing units and petroleum refinery.

Industry and infrastructure has been making rapid strides in Kerala. There are 1.8 lakh small scale industrial outfits and about 511 medium sized and large scale industries in Kerala. Kerala produces traditional manufacturing items such as coir, handlooms and handicrafts [which](#) employ around one million people. Around 1,80,000 small-scale industries employ around 909,859 Keralites, 511 medium and large-scale manufacturing firms are located in Kerala. The KSIDS has promoted more than 650 medium and large manufacturing firms in Kerala creating employment for 72,500 people. After independence, the state was managed as a democratic socialist welfare economy. The industries in Kerala are fertilizer factory, roof tile and Beedi manufacturing firms.

Tamil Nadu is the eleventh largest state by area and the sixth most populous state in India in 2011 census report. Since 2012, it is the second largest economy in India in terms of gross domestic product. The state has the highest number (10.56 percent) of business enterprises and stands second in total employment (9.97 percent) in India, compared to the population share of 6 percent. In 2013, Raghuram Rajan panel report, Tamil Nadu was ranked as the third most developed state in India based on a “Multi-dimensional Development Index”. The major industries of Tamil Nadu includes leather, textiles and engineering, automobiles, heavy industries such as iron and steel, cotton, silk and power, electrical and electronic equipment, cement, paper, watches and sterile industries.

### **C. Data base of the study**

This study was based on secondary data at the aggregate level. The required data were collected from various sources such as Annual Survey of Industries, (published by the Central Statistical Organization and maintained by Ministry of Statistical and Programme Implementation, Government of India, New Delhi), Economic survey and EPW Research Foundation. Based on the objectives of the study the whole reference period (1970-71 to 2013-14) was divided in to two phases. The period from 1970-71 to 1990-91 was treated as the pre reform period and the subsequent period from 1991-92 to 2013-14 was treated as the post reform period. Since the time period involved in the study elongated in both periods, there was a need to normalise the data to be recognised. All the referred variables were normalised by applying Net State Domestic Product (NSDP) as the deflator for all the states under study. As the data was available with different base series, for the purpose of the study the data was converted into 1970-71 base for pre reform period, and 1991-92 base for post reform period, by using base shifting methodology, in order to get the time series data with a single base. Productivity represents average labour productivity (production index/employment index) while the rate of inflation represents the growth of the GSDP deflator. Real wages were obtained by deflating the nominal wage index with the GSDP deflator.

## **D. Theoretical Background of the Study**

### **1. Efficiency**

Many attempts have been made by economists to quantify productive efficiency. Davis (1955) defined the absolute measure of efficiency  $E$  to be:  $E = y - 1 - k - m$  Where,  $y$  is the value of output and  $1, k, m$  are the values of different inputs at constant prices. This measure of efficiency is nothing more than a profit cost analysis. As in Schmookler (1952), Solow (1957), Kendrick (1961), efficiency can be quantified as the ratio between the values of outputs and inputs. This gives us the “partial Productivity” of each input since it is calculated by comparing output with each input (Kendrick, 1961). But this measure fails to give an overall measure of productive efficiency. The reason is that it does not take the composition of inputs or factor substitution into consideration. To solve this problem, Total Factor Productivity (TFP) was conceptualised. It is constructed by making an index that consists of a weighted average of inputs, using either relative prices or relative factor shares (Schmookler, 1952, Pagin, 1965, Bennett, 1967, Pack, 1984).

Different methods have been developed to measure TFP like Kendrick Arithmetic method (Kendrick, 1961) and Solow’s geometric index (Solow, 1957). But all these methods came under fire from Farrell (1957) who pointed to the inappropriateness of the ‘weights’. He argued that the selection of weights will be at the convenience of the user and the introduction of prices as weights, brings in an element of arbitrariness to the measure. This measure fails to distinguish the effects of inefficiency from that of other factors, whether endogenous or exogenous. These two conceptualisations of efficiency are termed as classical approach and the constraints in these led to the frontier approach to efficiency.

In his pioneering work, Farrell (1957) introduced three major efficiency concepts, two at the firm level and one at industry level viz., technical efficiency, price efficiency and structural efficiency. The estimation of Farrell’s efficiency is known as deterministic frontier production function based on inter-firm differences.

The work of Farrell was extended by Kopp (1981), which is known as scale efficiency. This work was followed by Aigner and Chu (1968), Timmer (1971), Afriat (1972), Richmond (1974) and Schmidt (1976). Measuring technical efficiency of firms by estimating frontier model was the latest econometric method developed. Followed by Farrell, the stochastic frontier production (SFPP) was developed by Aigner et al., (1977)

independently to measure mean efficiency of the firm. Meeseusem and Vanden Broeek (1977) and Battese and Coeli (1995) have directly applied this model. This was followed by DEA models (1978) to measure technical, scale, cost and allocative efficiencies.

In 1978, Leibenstein in his book covered X-efficiency theory and development. He has mentioned that both X-efficiency and allocative efficiency must be analysed carefully and tried to separate demand for factors of production in the market place from the utilisation of these factors in terms of the effort inputs; Also equilibrium of factors depend on the productivity of these factors, thus the degree of X-efficiency of effort input use in firms. With these theoretical backgrounds the investigator applied Data Envelopment Analysis (DEA) technique for the following reasons. The DEA technique involves the use of mathematical programming to estimate the efficiency of the agriculture/industry. DEA is a non-parametric, deterministic methodology for determining relatively efficient production frontier, based on the empirical data on chosen inputs and outputs of a number of entities called Decision Making Units (DMUs). From the set of available data, DEA identify reference points (relatively efficient DMUs) that define efficient frontier (as the best practice production technology) and evaluate the inefficiency of other interior points (relatively inefficient DMUs) that are below the frontier. The DEA provides a measure of efficiency that allows intra-farm comparison, as the efficiency measure is a pure number. The main advantage of DEA is that unlike Stochastic Function Approach, it does not require apriority assumption about the analytical form of the production function. Instead, it constructs the best practice production, solely on the basis of observed data. And therefore, the possibility of misspecification of the production technology is minimized.

## **2. Malmquist Productivity Index**

The productivity is most often defined as the output-input ratio. However, it is quite common among researchers to analyse aggregated multi-outputs and multi-inputs cases. This is formally defined as Total Factor Productivity (TFP) of a firm. In order to measure the changes in productivity, a productivity change index has to be built. The Total Factor Productivity Change (TFPC) index is simply calculated as a ratio of the TFP of a firm (i) in period (t) relative to the TFP of this firm (h) in period (t+1). This simple concept is used in case of the Malmquist TFP index. The Malmquist productivity index was introduced as a theoretical index by Douglas W. Caves, Laurits R. Christensen and Walter E. Diewert (Caves et al. 1982) and popularized as an empirical index by R. Fare, S. Grosskopf, B. Lindgren and

P. Roos (Fare et al. 1994). The big advantage of the Malmquist TFPC index is that the interpreting of its value is relative simple and it is not necessary to know the factor prices. Further advantage is that the Malmquist TFPC index allows indicating the factors that affect productivity and its changes. The index can be decomposed into three different factors, namely: Technical Change ( $\Delta T$ ), Technical Efficiency Change ( $\Delta TE$ ) and Scale Efficiency Change ( $\Delta SE$ ). It is important not to miss any of these factors because the results could be interpreted incorrectly. The DEA-based Malmquist index is one of the tools that does not require knowledge of the price level and gives information on factors affecting productivity changes over time (Coelli et al. 2005).

### **3. Granger's Causality**

The basic idea of Granger causality can be traced back to Wiener who conceived the notion that, if the prediction of one time series is improved by incorporating the knowledge of a second time series, then the latter is said to have a causal influence on the first. Granger later formalized Wiener's idea in the context of linear regression models. Specifically, two autoregressive models are fitted to the first time series, with and without including the second time series, and the improvement of the prediction is measured by the ratio of the variance of the error terms. A ratio larger than one signifies an improvement, hence a causal connection. At worst, the ratio is 1 and signifies causal independence from the second time series to the first. Geweke's decomposition of a vector autoregressive process led to a set of causality measures which have a spectral representation and make the interpretation more informative and useful by extending Granger causality to the frequency domain.

Causality among labour productivity, real wages and inflation is accepted in the theoretical literature that inflation may adversely affect productivity growth. Economists suggest three mechanisms by which inflation may have a negative effect on productivity (Freeman and Yerger (2000), Hondroyiannis & Papapetrou (1997), Jarrett and Selody (1982), Kumar et al. (2012), Narayan and Smyth (2009), Evangelia Papapetrou (2003) and Efthymios Tsionas (2003). The first mechanism depends on worker purchasing power while the others rely on firms' investment plans and mix of factor inputs. These mechanism's areas follow:

#### **a. Worker purchasing power**

Inflation leads to a decrease in worker purchasing power that reduces motivation and effort. Thus, inflation may negatively affect productivity through the worker purchasing power mechanism.

#### **b. Mix of factor inputs**

According to this proposed mechanism, inflation influences productivity in three ways. First, inflation may reduce productivity because it gives rise to an inefficient mix of factor inputs. Second, it may adversely affect productivity because of the choice of suboptimal factor input mixes, stemming from the distorted information content of price signals. Third, inflation reduces capital accumulation because it decreases tax reductions from depreciation and it raises the rental price of capital. Because of decreasing capital accumulation, productivity may decrease.

#### **c. Investment plans**

Firms generally respond to increasing uncertainty about inflation by raising inventories of buffer stock and decreasing expenditures on long-term basic research that leads to a reduction in productivity. Thus, increasing uncertainty about inflation may negatively affect labour productivity. Changes in productivity may also stem from changes in real wages. In the theoretical literature, there is a consensus regarding a positive relationship between productivity and real wages. In this framework, there are two basic arguments. The first argument depends on efficiency wage theory. According to this theory, higher real wages imply a higher cost of job loss for workers. When firms pay higher wages, workers exert greater effort to avoid being dismissed (Storm and Naastepad, 2007). Therefore, a rise in real wages will improve labour productivity by causing an increase in the cost of job loss. The second argument explains the positive relationship between productivity and real wages within a macroeconomic framework. This argument suggests that an increase in real wages will lead firms to substitute capital for labour by raising the cost of labour.

This substitution stemming from an increase in real wages will also raise marginal productivity (Wakeford, 2004). Causal relationships among productivity, real wages and inflation are also addressed by different theoretical models. These models and their forecasts regarding the direction of causation for the variables are summarised in Table-1. There are some theories that attempt to explain the direction of causality between productivity and real wages. The theories agree that there is a unidirectional causality, but they have different

views on the direction of the causality. First, efficiency wage theory asserts that the causality runs from real wages to productivity. This theory is based on the main hypothesis that productivity depends positively on real wages. Thus, it suggests that real wage increases (decreases) precede productivity increases (decreases).

**TABLE-1. Causality Issue**

Real Wages	→	Productivity	Efficiency Wage Theory
Productivity	→	Real Wages	Marginal Productivity and Bargaining Theory
Productivity	→	Inflation	Standard Theoretical View
Inflation	→	Productivity	Alternative Theoretical View

Second, marginal productivity theory and bargaining theory state that the causality runs from productivity to real wages because wages are determined with respect to productivity, i.e., higher productivity will cause higher real wages and lower productivity will cause lower real wages. Hence, this theory asserts that productivity increases precede real wage increases (Yusof, 2008). Table-1 shows that there are two theoretical views regarding the direction of causality between inflation and productivity. First, the standard theoretical view depends on the assumption that productivity growth is exogenous, and increases in worker productivity bring about decreases in the rate of inflation by raising the economy's aggregate supply. Therefore, this view argues that inflationary pressure may be reduced by productivity growth and henceforth, suggests a unidirectional flow of causality running from productivity to inflation. In other words, according to this view, changes in productivity precede changes in inflation rate. In contrast, the alternative theoretical view suggests that inflation may adversely influence productivity growth by decreasing worker purchasing power, distorting information content of price signals, disrupting investment plans and decreasing capital accumulation. Depending on these factors, this view argues that the causality flows from inflation to productivity (Freeman and Yerger 2000; Saunders and Biswas 1987).

#### **4. Cobb-Douglas Production Function**

The Cobb-Douglas production function is still today the most ubiquitous form in theoretical and empirical analyses of growth and productivity. The estimation of the parameters of aggregate production functions is central to today's work on growth, technological change, productivity and labour very much. Empirical estimates of aggregate production functions are a tool of analysis essential in macroeconomics and important theoretical constructs such as potential output, technical change or the demand for labour which are solely based on them. The origins of the Cobb-Douglas form dates back to the seminal work of Cobb and Douglas (1928), used data for the U.S. manufacturing sector for 1899-1922. At the time, Douglas was studying the elasticities of supply of labour and capital and how their variations affected the distribution of income (Douglas 1934). To make sense of and interpret the numbers obtained, Douglas needed a theory of production. He began by plotting the series of output (Day index of physical production), labour (workers employed) and fixed capital on a log scale. He noted that the output curve lay between the two curves for the factors, with the help of Cobb and Douglas estimated econometrically what is known today as the "Cobb-Douglas" production function. This seminal paper plays a paramount role in the history of economics, since it was the first time that an aggregate production function was estimated econometrically and the results presented to the economics profession. These results were taken, implicitly, as empirical support for the existence of the aggregate production function, as well as for the validity of the marginal productivity theory of distribution.

A major criticism at the time was that, estimates of the production function, although seemingly accurate, were based on such sparse data that it was hard to give them much credibility. The breakthrough came in using US census data, which was cross-sectional, and provided a large number of observations. Douglas presented the results of these findings, along with those for other countries, at his 1947 address as president of the American Economic Association. Shortly afterwards, Douglas went into politics and was stricken by ill health—resulting in little further development on his side. However, two decades later, his production function was widely used, being adopted by economists such as Samuelson Paul and Robert Solow (1960). The Cobb-Douglas production function is especially notable for being the first time an aggregate or economy-wide production function to have been developed, estimated and then presented to the profession for analysis. It marked a landmark change in how economists approached macroeconomics.

## E. Tools of analysis

### 1. DEA Model

There are two approaches to estimating the efficiency of the firm in the DEA approach viz., the output-oriented efficiency and the input-oriented efficiency. In the output oriented approach, efficiency is determined by maximum output that can be produced from an input bundle. In the input-based measure, the technical efficiency of the firm is evaluated by the extent to which all inputs could be proportionally reduced without a reduction in the output. Among number of DEA models, the two most frequently used ones (input oriented) are, CCR model (after Charnes, Cooper, Rhodes 1978) and BCC model (after Banker, Charnes and Cooper 1984) both of which are used in the study. The DEA model is used to estimate the technical, scale, cost and allocative efficiency, and to Malmquist Productivity indices of the industries under study.

#### a. Technical Efficiency

##### (i) CCR Model (based on constant returns to scale)

Charnes, Cooper and Rhodes introduced a measure of efficiency for each DMU that is obtained as a maximum of ratio of weighted outputs to weighted inputs. The weights for the ratio are determined by a restriction that the similar ratios for every DMU have to be less than or equal to unity, thus reducing multiple inputs and outputs to single “virtual” output without requiring pre-assigned weights. The efficiency measure is then a function of weights of the “virtual” input-output combination.

Formally, the efficiency measure for the DMU can be calculated by solving the following mathematical programming problem:

$$\max h_0(u,v) = \frac{\sum_{r=1}^S u_r Y_{ro}}{\sum_{i=1}^S v_i X_{io}} \dots\dots\dots (1)$$

Subject to

$$\frac{\sum_{r=1}^s u_r Y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, j = 1, 2, \dots, j_o, \dots, n \quad \dots\dots\dots (2)$$

$$u_r \leq 0, r = 1, 2, \dots, s \quad \dots\dots\dots (3)$$

$$v_i \geq 0, i = 1, 2, \dots, m \quad \dots\dots\dots (4)$$

where  $x_{ij}$  is the observed amount of input of the  $i^{\text{th}}$  type of the DMU ( $x_{ij} > 0, i = 1, 2, \dots, m, j = 1, 2, \dots, n$ ) and  $y_{rj}$  = the observed amount of output of the  $r^{\text{th}}$  type for the  $j^{\text{th}}$  DMU ( $Y_{rj} > 0, r = 1, 2, \dots, s, j = 1, 2, \dots, n$ ).

The variables  $u_r$  and  $v_i$  are weights to be determined by the above programming problem. However, this problem has infinite number of solutions since if  $(u^*, v^*)$  is optimal then for each positive scalar  $\alpha$  ( $\alpha u^*, \alpha v^*$ ) is also optimal. Following the Charnes-Cooper transformation (1962), one can select a representative solution  $(u, v)$  for which

$$\sum_{i=1}^m v_i x_{io} = 1 \quad \dots\dots\dots (5)$$

to obtain a linear programming problem that is equivalent to the linear fractional programming problem (1) - (4). Thus, denominator in the above efficiency measure  $h_0$  is set to equal one and the transformed linear problem for DMU can be written.

$$\max z_0 = \sum_{r=1}^s u_r Y_{ro} \quad \dots\dots\dots (6)$$

Subject to

$$\sum_{r=1}^s u_r Y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, j = 1, 2, \dots, n \quad \dots\dots\dots (7)$$

$$\sum_{i=1}^m v_i x_{io} = 1 \quad \dots\dots\dots (8)$$

$$u_r \geq 0, r = 1, 2, \dots, s \quad \dots\dots\dots (9)$$

$$v_i \geq 0, i = 1, 2, \dots, m \quad \dots\dots\dots (10)$$

For the above linear programming problem, the dual can be written (for the given DMU) as:

$$\min z_0 = \Phi_0 \quad \dots\dots\dots (11)$$

Subject to

$$\sum_{j=1}^n \lambda_j Y_{rj} \geq y_{r0}, r = 1, 2, \dots, s \quad \dots\dots\dots (12)$$

$$\Phi_0 x_{i0} - \sum_{j=1}^n \lambda_j x_{ij} \geq 0, i = 1, 2, \dots, m \quad \dots\dots\dots (13)$$

$$\lambda_j \geq 0, j = 1, 2, \dots, n \quad \dots\dots\dots (14)$$

Both of the above linear problems yield the optimal solution  $\Theta^*$ , which is the efficiency score (so-called technical efficiency or CCR efficiency) for the particular DMU and repeating them for each DMU  $j, j = 1, 2, \dots, n$  efficiency scores for all of them are obtained. The value of  $\Theta$  is always less than or equal to unity (since when tested, each particular DMU is constrained by its own virtual input-output combination too). DMUs for which  $\Theta^* < 1$  are relatively inefficient and those for which  $\Theta^* = 1$  are relatively efficient, having their virtual input-output combination points laying on the frontier. The frontier itself consists of linear facets spanned by efficient units of the data, and the resulting frontier production function (obtained with the implicit constant returns to scale assumption) has no unknown parameters.

**(ii) BCC model (based on Constant Returns to Scale)**

Since there are no constraints for the weights  $\lambda_j$ , other than the positivity conditions in the problem (11) - (14), it implies constant returns to scale. For allowing variable returns to scale, it is necessary to add the convexity condition for the weights  $\lambda_j$ , i.e. to include in the model (11) - (14) the constraint:

$$\sum_{j=1}^n \lambda_j = 1 \quad \dots\dots\dots (15)$$

The resulting DEA model that exhibits variable returns to scale is called BCC model, after Banker, Charnes and Cooper (1984). The input-oriented BCC model for the DMU<sub>0</sub> can be written formally as:

$$\min z_0 = \Theta_0 \quad \dots\dots\dots (16)$$

Subject to

$$\sum_{j=1}^n \lambda_j Y_{rj} \geq Y_{r0}, r = 1, 2, \dots, s \quad \dots\dots\dots (17)$$

$$\Theta_0 x_{i0} - \sum_{j=1}^n \lambda_j x_{ij} \geq 0, i = 1, 2, \dots, m \quad \dots\dots\dots (18)$$

$$\sum_{j=1}^n \lambda_j = 1 \quad \dots\dots\dots (19)$$

$$\lambda_j \geq 0, \quad j = 1, 2, \dots, n \quad \dots\dots\dots (20)$$

Running the above model for each DMU, the BCC efficiency scores are obtained (with similar interpretation of its values as in the CCR model). These scores are also called “pure technical efficiency scores”, since they are obtained from the model that allows variable returns to scale, and hence eliminate the “scale part” of the efficiency from the analysis. Generally, for each DMU the CCR efficiency score will not exceed the BCC efficiency score. What is intuitively clear since in the BCC model is each DMU is analysed “locally” (i.e. compared to the subset of DMUs that operate in the same region of returns to scale) rather than “globally”.

**(b) Scale efficiency**

Following the scale properties of the above two models (Cooper et al. 2000), the scale efficiency is defined as: for a particular DMU – the scale efficiency is defined as a ratio of its overall technical efficiency score (measured by the CCR model), and pure technical efficiency score (measured by the BCC model).

**(c) Cost Efficiency**

The standard measure of cost efficiency is obtained via a two stage process i) Estimate the minimum price-adjusted resource usage given technological constraints, and (ii) compare this minimum to actual, observed costs. Cost efficiency can be measured if input prices are available in addition to output and input data. Let  $x = (x_1, \dots, x_k) \in R_+^k$  denote a

vector of inputs and  $y=(y_1, \dots, y_m) \in R_+^m$  denote vector of outputs. Formally, the cost efficiency model can be specified as:

$$\begin{aligned} & \text{Min}_{z,x} \sum_{j=1}^m w_j x_j && \dots\dots\dots (21) \\ \text{s.t.} & z.Y \geq y_0 \\ & z.x \leq x_0 \\ & z_i \geq 0 \\ & \sum_{i=1}^n z_i = 1 \end{aligned}$$

where Y is an n x m matrix of observed outputs for n industries and x is an n x k matrix of inputs for each industry. z is a 1 x n vector of intensity variables and  $w = (w_1, \dots, w_k) \in R_+^k$  denoted input prices.

The constraints of the model (21) define the input requirement set given by:

$$L(y) = \{x, z, y \geq y_0, z x \leq x, z_i \geq 0, \sum_{i=1}^n z_i = 1\} \dots\dots\dots (22)$$

The input requirement set specifies a convex technology with Variable Returns to Scale (VRS), which is imposed by the constraint  $\sum_{i=1}^n z_i = 1$ . Leaving the constraint out of the model changes the technology to Constant Returns to Scale (CRS).

**(d) Allocative Efficiency**

Allocative efficiency is defined as a ratio of cost efficiency score to technical efficiency score. Both under CRS production technology and VRS production technology, this efficiency score was estimated for the present study.

Yun Zhang and Robert Bartels (1998), Saon Ray (2004), Mainak Mazumdar et al. (2009), Jabir Ali (2007), Manonmani (2014), Manonmani (2015), Sandeep Kumar Baliyan et

al.(2015) took different years as the Decision Making Units (DMUs) and analysed different forms of efficiency using DEA approach in manufacturing sectors.

## 2. Malmquist TFP index

The description below draws primarily upon the work of Fare et al. (1994), Fare et al. (1998) and Coelli et al. (1998). Let us assume that time period  $t$  is the base/current period and that period  $t+1$  is the future period. The Malmquist index measures Total Factor Productivity (TFP) change between two data points by calculating the ratio of the distances of each data point in relation to a common technology. Following the framework of Coelli et al. (1998), a production frontier representing the efficient level of output ( $y$ ) that can be produced from a given level of input ( $x$ ) is constructed, while making the assumption that this frontier can shift over time. The frontier ( $F$ ) is obtained in the current ( $t$ ) and future ( $t +1$ ) time periods. If inefficiency is assumed to exist, the relative movement of any given firm over time will depend on both its positions relative to the corresponding frontier (technical efficiency) as well as the position of the frontier itself (technical change). When inefficiency is ignored, then productivity growth over time will be unable to distinguish between improvements that arise when a firm catches up to the frontier or those that result from the frontier itself shifting over time. It is possible to employ the input-oriented Malmquist productivity index to decompose the productivity change between the two periods into technical change and technical efficiency change. The input-oriented Malmquist productivity change index is shown as,

$$M_{t+1}^t(y_{t+1}, x_{t+1}, y_t, x_t) = \left[ \frac{d_t(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)} \cdot \frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_{t+1}(y_t, x_t)} \right]^{\frac{1}{2}}$$

Where  $M$  is the productivity of the most recent production point ( $x_{t+1}, y_{t+1}$ ) (using period  $t+1$  technology) relative to the previous production point ( $x_t, y_t$ ) (using period  $t$  technology), and  $d$  is the input distance function. A value of  $M$  that is greater than unity indicates that there is positive total factor productivity growth between the two periods. Equation (1) also can be written as:

$$M_{t+1}^t(y_{t+1}, x_{t+1}, y_t, x_t) = \frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)} \cdot \left[ \frac{d_t(y_{t+1}, x_{t+1})}{d_{t+1}(y_{t+1}, x_{t+1})} \cdot \frac{d_t(y_t, x_t)}{d_{t+1}(y_t, x_t)} \right]^{\frac{1}{2}}$$

Or

$$M = E \times P$$

where

$$E = \frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)}$$
$$P = \left[ \frac{d_t(y_{t+1}, x_{t+1})}{d_t(y_{t+1}, x_{t+1})} \cdot \frac{d_t(y_t, x_t)}{d_{t+1}(y_t, x_t)} \right]^{\frac{1}{2}}$$

Furthermore, M is the product of a change in efficiency E as measured in period (t +1), period t and a measure of technical progress P as measured by shifts in the frontier over the same period.

Fare et al. (1994) suggests that technical efficiency change can be decomposed into scale efficiency and pure technical efficiency components. If the majority of inefficiency is due to the small size of operations, i.e., increasing returns to scale, then the DMUs will need to plan for expansion. On the other hand, pure technical inefficiency can usually be addressed in the short term without changing the scale of operations. Using this approach, it is thus possible to provide four efficiency and productivity indices for each firm and a measure of technical progress over time. They are: (1) technical efficiency change (E) (i.e., relative to a constant returns-to-scale technology); (2) technical change (P); (3) pure technical efficiency change (PT) (i.e., relative to a variable returns-to-scale technology); (4) scale efficiency change (S); and finally total factor productivity change (M). All indices are relative to the previous year. Hence, the output figures begin in year 2.

Once M is calculated, recalling that M indicates the degree of productivity change, if  $M > 1$  then a productivity gain will occur, whilst if  $M < 1$  a productivity loss will occur. An interpretation of changes in efficiency (E) is that technical efficiency increases (decreases) if and only if E is greater (less) than one. Technical progress (regress) will have occurred if P is greater (less) than one. An assessment can also be made of the major sources of productivity gains/losses by comparing the values of E and P. If  $E > P$ , then productivity gains are largely the result of improvements in efficiency, whereas if  $E < P$  productivity gains

are primarily the result of technological progress. In addition, an indication of the major source of efficiency change can be obtained by recalling that technical efficiency (E) is the product of pure technical efficiency (PT) and scale efficiency (S), such that  $E=PT \times S$ . Thus, if  $PT > S$ , then the major source of efficiency change is the improvement in pure technical efficiency whereas, if  $PT < S$ , the major source of efficiency is an improvement in scale efficiency. If  $TFPCH < 1$ , means that DMU productivity is decreased from period t to t+1; if  $EFFCH > 1$ , means technological efficiency is improved to some extent; on the contrary, if  $EFFCH < 1$ , shows technological efficiency is decreased; if  $TECHCH > 1$ , means the technology has improved; if  $TECHCH < 1$ , means the technology has declined; if  $PECH > 1$ , means that the pure technical efficiency has improved; if  $SECH > 1$ , means that in comparison to the period t, period t+1 has become close to a constant scale of return, which is gradually to the optimal size of a long-term approach.

Bjurek & Durevall (2000), Fu (2005), Basti & Akin (2008), Shallu Sehgal & Suparn Sharma (2011), Fulwinder Pal Singh (2012), Arnab Deb & Subhash Ray (2014) and Sandeep Kumar Baliyan (2015), have studied on different components of productivity growth using DEA based Malmquist productivity index in manufacturing sector.

### **3. Granger causality test**

In this study the causality issues examined by Zekeriya Yildirim (2015) was followed. The application of granger causality test involves the following steps:

#### **a. Unit-root test**

Econometric and time series models have been based on the assumption that the underlying data processes are stationary. Empirically, it has been shown that most of the macro variables are non-stationary in nature. Hence, the analysis of non-stationary series with conventional techniques gives rise to a fair possibility of spurious co-movement between the variables. In this context, the co-integration and error correction modelling have been suggested to confront the spurious regression and provide a short-run dynamics of causal relationship. Before doing any test of co-integration, it is necessary in the first place to ascertain that the concerned series are not I (0) and also the exact order of integration since co-integration between two variables arises only when they are of the same order. Hence, the test for unit-root becomes obvious.

In the present study non-stationarity or the presence of a unit-root was tested using the Augmented Dickey test. To test if a sequence  $Y_t$  contains a unit-root, two different regression equations were considered:

$$\Delta Y_t = \alpha + \gamma Y_{t-1} + \theta t + \sum \beta_i \Delta Y_{t-i} + \varepsilon_t \quad \dots\dots\dots (1)$$

$$\Delta Y_t = \gamma Y_{t-1} + \sum \beta_i \Delta Y_{t-i} + \varepsilon_t \quad \dots\dots\dots (2)$$

The first equation includes both a drift term and a deterministic trend, and the second does not contain an intercept but include the deterministic trend. In both the equations, the parameter of interest is  $\gamma$ . If  $\gamma = 0$ , the  $Y_t$  sequence has a unit-root. The estimated ‘t’ statistic is compared with the appropriate critical value to determine if the null hypothesis is valid. However, if the variables are non-stationary, they are tested for the possibility of a co-integrating relationship.

**b. Multi-Variate Co-integration Analysis**

The multi-variate co-integration technique developed by Johansen (1998), and Johansen and Juselius (1990) were used to test for the number of co-integrating vectors (co-integration rank) in the system. This test enables the estimation of more than one co-integrating relationship and also permits testing for the validity of any restrictions on co-integrating relationships implied by economic theory. This procedure has a further advantage when testing for co-integration. When there are ‘n’ series and (n-1) potential co-integrating relationships, it first tests the null hypothesis of zero co-integrating relationship and proceeds in step-wise fashion to test the null of higher number of such relationship up to (n-1).

The general form of the model for a higher order autoregressive process is:

$$\Delta x_t = \sum \pi_1 \Delta_{t-1} + \varepsilon_t \quad \dots\dots\dots (3)$$

where  $c_t$  is the (n x 1) vector of variables,  $e_t$  is an independently and identically distributed ‘n’ dimensional vector with zero mean, and variance matrix  $SP_1$  is a (n x 1) matrix, and its rank is equal to the number of independent co-integration vectors.

The rank of a matrix is equal to the number of its characteristic roots that differs from zero. Thus, the number of independent co-integrating vectors in the system can be determined

by checking the significance of the characteristic roots of p (estimated matrix). The test of the number of co-integration vector can be conducted using the following test statistics:

$$I_{\text{trace}}(r) = -T \ln(I - I_i) \dots\dots\dots (4)$$

$$I_{\text{max}}(r, r+1) = -T \ln(1 - I_{r+1}) \dots\dots\dots (5)$$

Where,  $I_i$  are the estimated values of the characteristic roots or eigen values obtained from the estimated p matrix and T is the number of usable observation. The trace test (equation 4) is the test statistic that tests for the null hypothesis that the number of co-integrating vector is less than or equal to 'r' against a general alternative. The maximum Eigen value test (equation 5) is the test statistics that tests the number of co-integrating vectors 'r' against the alternative of (r + 1) co-integrating vectors. Critical values for both tests are tabulated in Osterwald-Lenum (1992).

**c. Vector Error Correction Model (VECM)**

The purpose of the VECM is to focus on the short run dynamics while making them consistent with the long run solution. If a number of variables are found to be co-integrated with at least one co-integrating vector, then there always exists a corresponding error correction representation which implies that the changes in the dependent variable can be formulated as a function of the level of disequilibrium in the co-integration relationship and fluctuations in other explanatory variables. In other words, the error correction term in the VECM provides additional channel for the detection of Granger causality.

**Granger Causality**

If there is a long-run relationship among productivity, real wages and inflation, then a -causal relationship among the variables exists. However, the existence of such a long run relationship does not provide any evidence about the direction of causality. The Granger causality test allows analysis of the causality direction in both the short and long-run. In the presence of co-integration, the test depends on the following error correction models (ECMs):

$$\Delta pr_t = \mu_1 + \alpha_{pr} \hat{\varepsilon}_{t-1} + \sum_{i=1}^p \phi_{rwi}^{(1)} \Delta rw_{t-i} + \sum_{i=1}^p \phi_{ini}^{(1)} \Delta in_{t-i} + \sum_{i=1}^p \phi_{pri}^{(1)} \Delta pr_{t-i} + \varepsilon_t^{pr}$$

$$\Delta rw_t = \mu_2 + \alpha_{rw} \hat{\varepsilon}_{t-1} + \sum_{i=1}^p \phi_{rwi}^{(2)} \Delta rw_{t-i} + \sum_{i=1}^p \phi_{ini}^{(2)} \Delta in_{t-i} + \sum_{i=1}^p \phi_{pri}^{(2)} \Delta pr_{t-i} + \varepsilon_t^{rw}$$

$$\Delta in_t = \mu_3 + \alpha_{in} \hat{\varepsilon}_{t-1} + \sum_{i=1}^p \phi_{rwi}^{(3)} \Delta rw_{t-i} + \sum_{i=1}^p \phi_{ini}^{(3)} \Delta in_{t-i} + \sum_{i=1}^p \phi_{pri}^{(3)} \Delta pr_{t-i} + \varepsilon_t^{in}$$

Where  $\hat{\varepsilon}_{t-1}$  the lagged residual term is generated from the long-run relationship and is referred to as the error correction term. The short-run, long-run and strong causality are used to analyse the causal relationships in the applied time series literature. The long-run causality depends on a t-test, while the others rely on a joint F-test. The significance of the t-statistics related to the coefficient of the error correction term implies the long-run causality. If the F-statistics from the coefficients of the first difference of the variables are statistically significant, then there is short-run causality between the variables of interest. Strong causality is also determined by the significance of F-statistics on both the coefficients of the respective explanatory variables and the respective error correction term.

Arbelaez et al. (2011), Zekeriya Yildirim (2015), Jack Strauss and Mark E. Wohar (2004), Saten Kumar et al. (2009), Abdel-Aziz and Hala Fares (2010), Joao Paulo A. de Souza (2014) have analysed causal relationship existing among labour productivity wage and inflation relating to manufacturing sector.

#### 4. Cobb-Douglas Production Function

Cobb-Douglas Production Function is one of the most widely used production function in Economics and Management research. This production function not only satisfies the basic economic law but also in its computation and interpretation of the estimated parameters. The objectives of applying Cobb-Douglas production function is to estimate the co-efficient of inputs, their marginal productivities, factor shares in total output and degree of returns to scale. It is based on unitary elasticity of substitution of inputs and this production function has been widely applied in empirical studies.

The following model was applied to data on output and input for estimating the CD function:

$$Y = AK^\alpha L^\beta$$

Where

Y = Gross output

K = Fixed capital

L = Number of workers

A = Efficiency parameter

$\alpha$  = Co-efficient of fixed capital (Elasticity of output with respect to capital)

$\beta$  = Co-efficient of Labour (Elasticity of output with respect to employees)

The logarithm of both sides of the above model was taken to convert the equation into linear form. Its log transformation is specified below:

$$\log Y = \log A + \alpha \log K + \beta \log L + u.$$

The efficiency parameter (A) and the coefficient of the inputs were estimated by applying the above Parameters ' $\alpha$ ' and ' $\beta$ ' representing individually the proportionate change in output for a proportionate change in Capital and Labour. The two coefficients are taken together to measure the aggregate proportionate change in output for a given proportionate change in labour, capital and raw material. This implies that  $\alpha + \beta$  shows the degree of returns to scale.

If  $\alpha + \beta > 1$ , it would imply that the output increase would be more than proportionate to the increase in inputs (there will be increasing returns to scale) if  $\alpha + \beta < 1$ , it would imply that the output increase would be less than proportionate to the increase in input (there will be decreasing returns to scale) and if  $\alpha + \beta = 1$  the output would just increase (there will be constant returns to scale).

Equation

$$\text{Log } V = \log A + \alpha \text{ Log } K + \beta \text{ Log } L + \mu$$

V=Gross value added

K=Fixed capital

L=Number of employees

$\mu$ =Elasticity of output with respect to capital

$\beta$ =Elasticity of output with respect to employees

Marginal product of labour ( $MP_L$ ) and capital ( $MP_K$ ) can be obtained by applying the following formula:

$$MP_L = \delta V / \delta L = \alpha V / L$$

$$MP_K = \delta V / \delta K = \beta V / K \text{ and}$$

Marginal Rate of Technical Substitution ( $MRTS_{LK}$ ) of labour for capital is calculated as follows:

$$MRTS_{LK} = MP_L / MP_K$$

Laxmi Narayan (2003), Sarma and Appa Rao (1991), Indrakant and Muppalla Sambasiva Rao (1993), Moyazzem Hossain, Tapati Basak and Ajit Majumder (2012), have made use of Cobb-Douglas production function in their studies to estimate returns to scale, factor intensity and type of technology.

## 5. Exponential Growth Function

To find out the annual trend rates in various factor productivity indices, unit-labour cost and capital intensity, the exponential growth function of the following form was used.

$$Y = AB^t$$

where

Y = Dependent variable;

A = Constant;

B = Parameter; and

t = Time factor

The value of A and B are estimated by converting the exponential equation into linear function of the form:

$$\text{Log } Y = \text{Log } A + t \log B.$$

## 6. Annual Growth Rate

The annual growth rate was calculated by using the formula

$$\text{AGR} = \frac{Y_t - Y_0}{Y_0} \times 100$$

AGR = Annual Growth Rate

$Y_t$  = Value in the current year

$Y_0$  = Value in the previous year

## 7. Co-efficient of Variation (C.V.)

To measure the percentage variation in the variables the Co-efficient of Variation (C.V.) was used i.e.:

$$\text{Co-efficient of variation} = \frac{\sigma}{\bar{X}} \times 100, \text{ where}$$

$\sigma$  = Standard deviation

$\bar{X}$  = Arithmetic Mean

## 8. Other Tools

Besides the above mentioned percentages, graphs and diagrams other tools were also used to estimate different outputs like computer software such as DEAP version 2.1, Eviews, Spss.16 and Microfit for windows.

## **F. Concepts and Definitions used**

### **1. Fixed Capital**

Fixed capital represents the depreciated value of fixed asset owned by the factory as on the closing day of the accounting year. Fixed assets are those that have a normal productive life of more than one year. Fixed Capital includes land, buildings, plants & machinery, furniture & fixtures, transport equipment, water systems and road ways and other fixed assets such as hospital, school etc. used for the benefit of industrial personnel.

### **2. Number of Workers**

Workers are defined to include all persons employed directly or through any agency whether for wages or not, and engaged in any manufacturing process. Labour engaged in the repair and maintenance or production of fixed assets for factory's own use or labour employed for generating electricity or producing coal, gas etc., are included. However, persons holding positions of supervision or management or employed in administrative office, store keeping section and welfare section, sales department, who are also engaged in the purchase of raw materials etc. and in production of the fixed assets for the factory, and staff of watch and ward are all excluded.

### **3. Wages**

Wages are defined to include all remuneration capable of being expressed in monetary terms and also payable more or less regularly in each pay period to workers (defined above) as compensation for work done during the accounting year. It includes (a) direct wages and salary (i.e. basic wages/salaries, payment of overtime, dearness, compensatory, house rent and other allowances); (b) remuneration for the period not worked (i.e. basic wages, salaries and allowances payable for leave period, paid holiday, lay-off payments and compensation for unemployment, if not paid from sources other than employers); (c) bonuses and ex-gratia payment paid both at regular and less frequent intervals (i.e. incentive bonuses, good attendance bonuses, productive bonuses, profit sharing bonuses, festival or year-end bonuses etc. The wages are expressed in terms of gross value i.e., before deduction for fines, damages, taxes, provident fund and employee's state insurance contribution and so on.

### **4. Gross Output**

Gross output is defined to include the ex-factory value of products and by-products manufactured (as defined above) during the accounting year. It also includes the receipts for non-industrial services rendered to others, the receipt for work done for others on materials supplied by them, value of electricity produced and sold, and net balance of goods sold in the same condition as purchased. The term gross output, value of output and total output has been used in the text interchangeably to mean same thing.

## **5. Technical Efficiency**

Technical Efficiency refers to the ability of the firm to maximise output from a given set of inputs (Farrell 1957).

## **6. Scale Efficiency**

Scale efficiency is the ability of the firm to equate its output obtained at the minimum point of long run average cost curve. In other words, the quantum of input used exactly equals the required input associated with constant returns to scale.

## **7. Allocative Efficiency**

Allocative efficiency refers to the response to the economic signals and choice of optimum input combination, given the relative input prices.

## **8. Cost Inefficiency**

Cost inefficiency of a firm arises when actual cost of production exceeds the minimum cost – the amount by which a firm lies below the production frontier and above its cost frontier can be referred to as measure of cost inefficiency.

## **9. Labour Productivity**

It is the ratio of output to the ratio of labour input (No. of employees)

## **10. Capital Productivity**

It is the ratio of output to the ratio of capital input (fixed capital)

## **11. Capital Intensity**

It is the ratio of capital (Fixed capital) divided by ratio of labour (No. of employees)

## **12. Marginal Productivity of Labour (MP<sub>L</sub>)**

Marginal Productivity of Labour (MP<sub>L</sub>) may be defined as the ratio between a change in output in a given economy or industry for a given time period and change in employment of that economy or industry for similar period.

## **13. Marginal Productivity of Capital (MP<sub>K</sub>)**

Marginal Productivity of Capital (MP<sub>K</sub>) is the additional output resulting from the use of an additional unit of capital (ceteris paribus, or assuming all other factors are fixed). It equals 1 divided by the incremental capital-output ratio. It is the partial derivative of the production function.

## **14. Marginal Rate of Technical Substitution (MRTS)**

In economic theory, the Marginal Rate of Technical Substitution (MRTS) or the Technical Rate of Substitution (TRS) is the amount by which the quantity of one input has to be reduced when one extra unit of another input is used, so that the output remains constant.  $MRTS_{LK} = MP_L \div MP_K$  where  $MP_L$  and  $MP_K$  are the marginal products of labour and capital respectively. In other words, it shows the rate at which one input (e.g. capital or labour) may be substituted for another, while maintaining the same level of output. The  $MRTS_{LK}$  can also be seen as the slope of an isoquant at the point in question.

## **15. Returns to Scale**

The term returns to scale arises in the context of a firm's production function. It explains the behaviour of the rate of increase in output (production) relative to the associated increase in the inputs (the factors of production) in the long run. In the long run, all factors of production are variable and subject to change due to a given increase in size (scale).

## **16. Economies of scale**

Economies of Scale show the effect of an increased output level on unit costs.

## **17. Constant Returns to Scale (CRS)**

If the output increases by that same proportional change as all inputs change, then there are constant returns to scale.

### **18. Decreasing Returns to Scale (DRS)**

If the output increases by less than that proportional change in inputs, then there are decreasing returns to scale.

### **19. Increasing Returns to Scale (IRS)**

If the output increases by more than that proportional change in inputs, there are increasing returns to scale.

## **G. Limitations of the Study**

The limitations of the present study are as follows:

1. Besides theoretical consideration, the choice of variables was guided by the availability of data.
2. The scope of the study was restricted up to the period 2013-14, since the latest data was available up to this period.
3. This study was confined to southern states of India. The findings and inferences emerging out of this study may not suit other set of states and other reference periods.

Despite these limitations, the findings are indicative of the trends in this field of study and offer scope for further research in the future.