CHAPTER FOUR

CONCEPTUAL & MEASUREMENT ISSUES RELATED TO INDUSTRIAL PRODUCTIVITY

4.1 Having discussed the trend & composition of industrial production in Assam in the previous chapter, we would like to shift the focus of our investigation into the measurement of productivity in the manufacturing sector of Assam as a whole and also in the different constituents of it. As mentioned in the introduction, data base of the Annual Survey of Industries (ASI) are used for this exercise. This means, the exercise is limited to only the Registered Manufacturing sector. Unregistered manufacturing sector is no doubt, important in terms of its contributions to total industrial output and employment generation. Yet this Segment of Manufacturing Sector could not be included in the exercise due to lack of consistent dataset needed for productivity analysis. Measurement of productivity in general and productivity in manufacturing industry in particular involve several tricky conceptual and empirical issues. Hence, before taking up the actual job of measuring productivity of Registered Manufacturing Sector in the state, a review of these issues is presented in this chapter. This chapter is organized in four sections.

In section II, the different concept of productivity and their implications are discussed. Section III is devoted to the different approaches of measurement of Total Factor Productivity (TFP). Section IV is divided into two sub-sections. In subsection IV.1, the empirical issues of estimating output and input measurement are dealt with. In Sub-section IV.2, some of the empirical studies of TFP on Indian industries are presented. The broad discussions on the chapter are summed up in section V.

4. 2.1. Productivity: Its different notions

The term 'productivity' is difficult to define precisely as different people put it differently. In general, the concept is concerned with the efficiency with which...
the inputs are converted into output. It, thus, refers to the performance of factors of production in terms of output.

Literature recognizes several types of productivity measures depending upon the purposes and/or data availability for particular investigation. However, there are broadly two productivity measures viz. single factor productivity or partial factor productivity e.g. labour and/or capital productivity/or material productivity and the multifactor productivity (MFP) or total factor productivity (TFP).

The partial productivity indices can be defined as the ratio of any industry's total output/or GVA to that industry's each category of inputs. Following OECD Manual (2001), the concept of Productivity measure covers the types of input and output measurements. Output is generally measured either in terms of gross or in terms of value added levels. Corresponding to each type of output measurement there is partial or single factor measurements of labour and capital. Labour/or capital productivity based on gross output or on GVA is defined as a ratio of quantity index of gross output or GVA to the quantity index of labour or capital input. It reflects the time profile of how labour or capital is used to generate output or GVA.

**Demerits:**

Partial productivity index of a given input reflects the combined influence of other inputs as well as other aspects of production process e.g. technical, managerial and efficiency change within and between firms, influence of scale economies, capacity utilization and measurement errors. It thus partially reflects the productivity of the particular inputs in terms of their individual capacities. It is to be noted that labour productivity is sometimes misinterpreted as technical change or as the productivity of individual in the labour force only. Being a partial measure, such an interpretation would not be valid. The combined influence does not leave out any direct effect of technical change irrespective of their nature. The Disembodied technical progress generally enhances production possibilities for a particular set of inputs and therefore affects labour productivity. The embodied technical
change by its very nature operates through capital goods and intermediate inputs and therefore affects labour productivity. In other words, embodied technical progress is associated with the increases in output due to improved quality of factor inputs (both labour and capital). The process of outsourcing i.e. the degree of substitution of primary inputs such as labour and capital for intermediate inputs also has a bearing on the productivity of the primary inputs which may cause overestimation and underestimation of their individual level of productivity as per higher and lower degree of outsourcing. However, in case of value added based productivity measure, both labour and capital with respect to outsourcing and changing vertical integration tend to be less responsive to process of substitution between intermediate inputs than gross output based measures. Because, capital input when measured as a flow of services adjusted for changes in the quality of investment goods, the capital measure converts to embodied technical change into a larger-smaller flow of constant-quality capital services. Hence, rise in quality of capital goods indicates a larger amount of capital services. Thus, partial productivity measures are subjected to a limitation, where capital is increasing overtime. For example, partial productivity of labour may show an increase but this could be more a reflection of rising capital labour ratio rather than pure technical progress. Like labour productivity, capital productivity is also a partial measure and hence cannot be considered as the single most representative of overall technical change. Besides, partial productivity measures assume about equi-proportionate changes in input coefficients which is unrealistic (Rao, 1996).

**Merits:**

In spite of the above limitations of partial factor productivity indices, value added based labour productivity is useful, at aggregate level for analyzing micro-macro links e.g. the industry contribution to economy-wide labour productivity and economic growth. It also forms a direct link to a widely used measure of living standards. From policy perspective, it is used as a reference statistic for wage bargaining. Capital productivity measure is useful to know the extent to which output growth can be achieved with lower welfare
cost in the form of foregone consumption. However, the partial productivity indices, to some extent, provide some idea to ascertain the efficiency with which the individual inputs are utilized. Thus, it may be helpful in ascertaining some of the causes of stagnation or slowdown of growth in developing countries like India (Ahluwalia, 1985).

4. 2.2. Total factor productivity (TFP)

TFP is defined as the proportion of output that cannot be explained by the inputs used in the production process (Comin, 2006). In other words, it is the increase in output growth which is not caused by the factor accumulation. Thus, TFP includes all those factors which contribute to generating output other than labour and capital. According to the literature this could be learning by doing, managerial capabilities and organizational competence, research and development, inter-sectoral transfer of resources, increasing returns to scale, embodied technological progress and diffusion of technology (Felipe, 1999). TFP captures the effects of qualitative improvements that allow output to increase without any use of additional inputs. This means making better use of resources that are available, such as the introduction or upgrading of technology, innovation, better management techniques, gains from specialization, improvements in efficiency and workers' education as well as skills & experience (SERI, 2008). Thus, TFPG is defined to encompass technological progress and the change in technical efficiency. Technological progress may be defined as the advances in knowledge relating to the art of production which may take the form of new goods produced or new methods of organization. Technical efficiency relates to the process of combining factors of production in generating output. Technical progress can be conceptualized in terms of shifts in the production function (Solow 1957) whereas technical efficiency measures the distance between the actual and the frontier or the maximum attainable levels of output (Catching up component). TFP is a residual measure; where productivity is the label attached to the part of output growth which is not readily explained by increases in factor inputs (Acharya 2004). Based on using specific kind of input framework, TFP is classified into two categories viz. labour-capital
based multifactor productivity (MFP) and capital, labour, energy, material, services based MFP or TFP.

The multifactor productivity or TFP using two input framework viz. labour and capital based on value added is defined as a ratio of quantity index of value added to the quantity index of combined labour and capital inputs. Quantity index of combined labour and capital is the quantity index of different types of labour and capital each weighted with its current price share in total value added.

The multi factor productivity or TFP using KLEMS (capital, labour, energy, material, services) framework based gross output function can be also defined as the ratio of quantity index of gross output to the quantity index of combined inputs. Here, quantity index of combined inputs is the quantity index of different types of capital, labour, energy, material, and services, each weighted with its current price share in the total gross output. It also shows the time profile of how productively joint inputs are used to generate output.

**Merits:**

Labour-Capital MFP is useful to study micro-macro relations, e.g. the industry contribution to the economy wide MFP growth and living standards. It is also helpful in analysing the structural change of an economy. Both types of MFP are considered as the indicators of industry's performance in terms of growth of income per unit of primary input combined in spite of their limitations a good measure of technology change. KLEMS based TFP measure is commonly used to analyze industry level as well as sectoral technical change. KLEMS-MFP is conceptually sound to measure technical change by industry than the labour-capital MFP as the role of intermediate inputs in production process is recognized in it.

**Demerits:**

Conceptually, labour-capital MFP and KLEMS- MFP are not in general an accurate measure of technical change. They reflect the joint effects of
disembodied technical change, economies of scale, efficiency change, degree of capacity utilization and measurement errors. Under KLEMS framework, if capital input measure is considered as the aggregation of all types of assets, each weighted by their corresponding user costs, and based on capital goods prices that reflects quality change, then the effects of embodied technical change can be picked up by the capital input term. It is difficult to get required data set to measure KLEM based MFP from input-output tables which would have rare timely coincidence with national accounts. Also this measure is less prone to inter industry links and aggregation across industries than the value added MFP. However, several scholars argue that TFP as a residual measure is an arbitrary concept. It is highly sensitive to the measurement of factor inputs. Thus, in absence of adjustment in the quality of inputs i.e. labour and capital, there is every chance that the residual will be high. On the other hand, if the qualities of the inputs are properly accounted then it will be small. Therefore, it is seen that under-adjustments of the factor inputs in the developed countries result higher TFP or residual and over-adjustment in case of developing countries turns it small. Thus, it is clear that it is catch-all phrase, and its meaning differs substantially with the methodology and the way the factor inputs are aggregated and measured (Chen, 1997).

4.3 Approaches to measure Total factor Productivity:

Literature on TFP has continued to grow substantially, reflecting the advances in the theory of production and the theory of index numbers and aggregation. However, there are basically three major approaches to the measurement of productivity growth (Diewert 1980). They are (i) Growth Accounting/Index Number Approach (ii) Econometric /Parametric Estimation of Production or Cost Functions and (iii) Efficiency Frontier Models Approach. The Efficiency Frontier Models Approach can further be studied either with estimating Stochastic Frontier Production Function (SFPF) or using Non-parametric Approaches viz. Malmquist TFP Index and Data Envelopment
Analysis (DEA). Literature is inconclusive on the best method to estimate TFP growth. Typically, no measure of TFP is necessarily the best for all purposes. However, the Index Number Approach is useful for estimating productivity growth as well as levels when measurement error is small. Data Envelopment Analysis is best when technology is heterogeneous and returns to scale are not constant. In case of measurement or optimization errors are non-negligible, the Parametric Approaches are preferred (Biesebroeck 2007). It is seen that, the estimation of an aggregate production function creates lots of difficulties for the researchers; including possible endogeneity of capital and labour. These might have impact on the elasticity estimates obtained and thus the values of TFP obtained (Akilno 2005).

We now proceed to discuss the approaches in some details.

4.3.1 GROWTH ACCOUNTING APPROACH

In this approach, separation of output change due to capital accumulation and technical progress can be made in terms of movement along a production function and as a shift in the function respectively. In general, the function used in this approach is assumed to be linearly homogeneous with a shift factor (time) which is described as a proxy for capturing the effects of technical progress. TFP indices are categorized into two separate groups: (i) Arithmetic TFP indices appeared first in the works of Abramovitz (1956) and Kendrick (1961) and (ii) Geometric or Divisia TFP indices, first used in the works of Solow (1957) and Jorgenson and Griliches (1967). Kendrick arithmetic index of TFPG from base year 0 to period 1 can be expressed as:

$$ p = \left[ \frac{V_{t}/V_0}{\sum_{i=1}^{k} W_{i,0} X_{i,0} / \sum_{i=1}^{k} W_{i,0} X_{i,0}} \right] - 1 \quad [4.1] $$

Where, $p$ denotes the rate of TFP change with respect to time (i.e. $dp/dt$). $W_{i,0}$ is the share of input $i$ in the base year. $X_{i}$ is the quantity of input $i$. $V_0$ and
are the gross value added in period 0 and 1 respectively. Kendrick index is based on a linear production function implying that the marginal products of inputs are constant. So, this index fails to cater to possible diminishing marginal productivity of capital.

The Divisia or geometric TFP indices are based on Cobb-Douglas (C-D) production function with assumption of constant returns to scale (CRS) and autonomous and neutral technical change. This approach uses a form of geometric mean of factor inputs \((X_i, t)\) where weights are given as per respective income shares \((S_i)\). The divisia index can be shown as follows:

\[
\theta_i = \frac{d\ln V}{dt} \left[ \sum_{i=1}^{k} S_i \frac{d\ln X_i}{dt} \right]
\]

This index was introduced by Solow in 1957. Divisia index is a less restrictive form. In this index, the relationship between output, input and time is described through translog production function. The importance of this index has been highlighted by Ritchter (1966), Jorgenson and Griliches (1967), Christensen and Jorgenson (1970), Hulten (1973) and Diewert (1976). This index satisfies both the time reversal and factor reversal properties. Time reversal test is satisfied if the Divisia Index is symmetrical in different directions of time. Factor reversal test requires that growth rates of Divisia Index of prices and quantities add up to the growth rate of value. The major shortcoming of this index is that it assumes continuous and instantaneous changes and hence its value normally depends on the path of integration (Ritcher, 1966; Jorgenson and Griliches, 1967). Therefore, its application is limited only in theoretical analysis and not in economic research where most of the data is available in discrete form.

Tornquist has provided a discrete time approximation to the Divisia Index which makes it possible to apply in empirical research (Diewert 1976). Under Divisia-Tornquist approximation, the log arithmetic differences of outputs and inputs with weights of their factor shares in period \((t)\) and \((t-1)\) provides the
TFPG between the periods. The average rate of technical change is expressed as:

\[
\bar{\theta}_t = \ln\left(\frac{V_t}{V_{t-1}}\right) - \sum_{i=1}^{k} \bar{S}_i \ln\left(\frac{X_{t,i}}{X_{t-1,i}}\right) \tag{4.3}
\]

Where, \( \bar{S}_i = \frac{1}{2}[S_{ij} + S_{ij-1}] \)

**Merit:**

According to Diwert (1976) the Tornqvist index is an exact measure of technical change if the underlying production function is a Translog one and exhibit constant returns to scale.

**Demerits:**

The rationale of growth accounting approach ultimately based on the existence of aggregate production function and on the validity of aggregate marginal theory of factor pricing. This approach needs to impose the assumptions like Constant returns to scale (CRS) and perfect competition (Felipe 1999).

**4.3.2. ECONOMETRIC ESTIMATION OF PRODUCTIVITY**

Under this approach, TFP is measured using either Production Function or Cost Function framework.

**Production Function Approach**

In the production function approach, econometric techniques are used to measure the parameters like returns to scale, elasticity of substitutions between inputs and technical bias along with technical progress. In this approach, time is often used to represent the disembodied technical progress. Technical progress is considered in this approach as residuals or unexplained part of output. TFP, in this approach is taken synonymous for technical progress because of the assumption of no inefficiency in production. However, an alternative form of technical progress is through
efficiency parameter where the parameter is assumed to be time dependent variable. In this case, technical change occurs with change in time and yields change in output due to factors other than changes in input quantities. Neoclassical production function framework is very often used to estimate TFPG, using time series data. The different specification of production functions used in the estimation of TFPG is as follows:

**Cobb-Douglas (C-D) Production Function:**

The C-D function in its most commonly used log linear form with Hicks neutral technical progress can be expressed as:

\[ \ln V = a + \lambda t + \alpha \ln L + \beta \ln K + u \]  

[4.4]

Where, \( V \) = gross value added, \( L \) = Labour, \( K \) = capital and \( u \) = Error term. \( \alpha \) and \( \beta \) are output elasticity of \( L \) and \( K \) respectively. \( \lambda \), denotes the measure of TFPG. In this form, the sum of elasticity between \( L \) and \( K \) represents returns to scale. The ordinary Least Square (OLS) technique is used to obtain the estimates of \( \alpha \), \( \beta \), and \( \lambda \). The ratio form of the function can be shown as:

\[ \ln (V / L) = a + \beta \ln (K / L) + (\alpha + \beta - 1) \ln L + \lambda t + u \]  

[4.5]

A restrictive form of C-D function with assumption of CRS is expressed as:

\[ \ln \frac{V}{L} = a + \beta \ln \frac{K}{L} + \lambda t + u \]  

[4.6]

**Constant Elasticity of Substitution (CES) Production Function:**

The CES function is expressed as:

\[ V = Ae^{\beta \rho} \left[ (1 - \delta) K^{-\rho} + \delta L^{\rho} \right]^{\sigma / \rho} \]  

[4.7]
Where, $\lambda$ is the Hicks neutral disembodied technical change, $\delta$ is the distribution parameter and $\upsilon$ is the scale parameter and $\rho$ is the substitution parameter. The relationship between $\rho$ and elasticity of substitution ($\sigma$) is:

$$\sigma = \frac{1}{1-\rho}$$

The CES function cannot be transformed into a linear function and therefore, OLS technique cannot be used for obtaining the estimates of parameters. However, Judge et al. (1980) describe several non-linear algorithms e.g. Gauss, Quasi Newton etc. for estimating the parameters.

SMAC (1961) procedure is another popular indirect estimation method of CES function. In this procedure, it requires to test first the assumption of unitary elasticity of substitution. Under the assumption of CRS, perfect competition and equality of real wage rate to marginal product of labour, the estimation equation with inclusion of time can be cited as:

$$\ln(V/L) = a + b \ln w + c t + u$$ \hspace{1cm} [4.8]

Where, $b = \sigma$, $c = \lambda(1-b)$ and hence $\lambda = c/1-b$. The SMAC form of CES function under non-constant returns to scale can be shown as:

$$(\ln V/L) = a + b \ln w + c t + d \ln L + u$$ \hspace{1cm} [4.9]

Where, $b = \frac{\upsilon}{\upsilon + \rho}$, $c = \frac{\lambda \rho}{\upsilon + \rho}$, $d = \frac{\rho(\upsilon - 1)}{\upsilon + \rho}$

Solving the equations, we have

$$\upsilon = (d - c + 1)/1 - b, \rho = (d - b + 1)/b, \lambda = c/1-b, \sigma = b/1+d$$

One of the advantages of the estimation of SMAC form is that it does not require capital data. Moreover, under SMAC framework, estimation of elasticity of substitution can be done directly. In the estimation of SMAC form the OLS technique is generally used.

In empirical research, Kementa's single equation method (1967) and Bairam specification (1989) of CES function are often used. Kementa's method is
based on linear approximation of CES function in which logarithms of the function expanded in a Taylor's series about an initial value of substitution parameter ($\rho$). He used the following approximation of CES function:

$$
\ln\left(\frac{V}{L}\right) = a + \lambda t + (\nu - 1) \ln L + \nu \delta \ln K / L
$$

$$
-\frac{1}{2} \rho \nu \delta (1 - \delta) [\ln (K / L)]^2
$$

[4.10]

In case of CRS, the function will be as follows:

$$
\ln\left(\frac{V}{L}\right) = a + \lambda t + (\delta) \ln K / L - \frac{1}{2} \rho \delta (1 - \delta) [\ln K / L]^2
$$

[4.11]

Both the estimating equations have limitations. The estimated values of elasticity of substitution from such measurement very often lie outside the plausible limits because of indirect estimation of the parameter (Chen 1976).

Bairam (1989) developed a variant of CES function to estimate technical progress. The specification is generally expressed in a general Box-Cox model (1964), which is as follows

$$
\frac{V^{\lambda-1}}{\lambda} = A + \psi t + \alpha \frac{L^{\lambda-1}}{\lambda} + \beta \frac{K^{\lambda-1}}{\lambda}
$$

[4.12]

Where, $-\infty < \lambda < \infty$ and $\alpha$ and $\beta > 0$.

A time variable is included in the model to allow for the effects of quality change overtime. The TFP can be obtained from the model as:

$$
\tau = \left[ (\lambda \psi + 1)^{\lambda} - 1 \right]
$$

[4.13]

Assuming $\lambda = 0$, the function becomes a C-D function:

$$
\ln V = A + \psi t + \alpha \ln L + \beta \ln K
$$

[4.14]

Where, $\alpha + \beta$ provides the measure of returns to scale and ($\psi$) refers to Hicks neutral technical progress. The Maximum Likelihood (ML) Method is used to estimate the parameters of the function.
Variable Elasticity of Substitution (VES) Production Function or Translog Production Function:

In Translog production function, elasticity of substitution between inputs is variable and dependent on capital labour ratio (K/L). The following are some of the widely used specifications of this kind:

Hildebrand and Liu (1970) used the following functional form of VES with Hicks-neutral disembodied technical progress.

\[ \ln(V/L) = \ln(A) + b_2 \ln(W) + b_3 \ln(K/L) + \lambda t + e \quad [4.15] \]

The elasticity of substitution (\( \sigma \)) between Labour and Capital can be derived as:

\[
\sigma = \frac{b_2}{1 - \frac{b_3}{S_k}} \quad [4.16]
\]

Where, \( S_k \) is the share of capital.

Lu et al (1968) developed a functional form of VES function with Hicks-neutral disembodied technical change. The logarithmic form of the function is as follows:

\[ \ln(V/L) = \ln(A) + \alpha_1 \ln(W) + \alpha_2 \ln(K/L) + \lambda t + u \quad [4.17] \]

Christensen et al (1973) have developed a translog production function which imposes relatively few a priori restrictions on the properties of the underlying technology. It allows for VES, variable scale elasticity and non-neutral technical progress. Their translog function with two inputs framework can be expressed as:

\[ \ln(V) = \alpha_0 + \alpha_L (\ln L) + \alpha_K (\ln K) + \alpha_T T + \frac{1}{2} \beta_{LL} (\ln L)^2 + \frac{1}{2} \beta_{KK} (\ln K)^2 + \frac{1}{2} \beta_{TT} T^2 \]

\[ + \beta_{LT} (\ln L) T + \beta_{KT} (\ln K) T + \beta_{LK} (\ln L)(\ln K) \quad [4.18] \]
Where, $\alpha$ and $\beta$ are the parameters of the function. $T$ is time variable showing non-neutral technical change. $\alpha_T$ is the rate of autonomous TFPG. $\beta_{TT}$ is the rate of change in TFPG. The bias in TFP is viewed from the elasticity $\beta_{KT}$ and $\beta_{LT}$. The estimates of the parameters of translog function are generally obtained by direct estimation of the production function or by using OLS Technique.

One of the major limitations of the translog function is that it may not satisfy the positive monotonicity\(^1\) and concavity\(^2\) conditions. However, there may be some range of inputs and output data points, where the properties do hold, the function can be regarded well behaved and provides a good representation of the underlying technology. The use of a sequence of F-tests is required to test the conditions of well behavedness and constant returns to scale in a translog function.

**Cost function approach**

A production function always corresponds to a cost function and vice versa. Thus, the duality theory basically establishes the fact that under certain weak regularity conditions, a unique correspondence exists between the production and cost functions. The recent application of duality theory to problems in economics has resulted in many useful results for the study of production and cost relationship. Hotelling (1932) introduced the formulation of dual and later on Shephard (1953, 1970), Uzawa (1964) and Mcfadden (1978) have made contributions to the subject. The basic results of duality theory are that the well-behaved production function and the corresponding cost function are equivalent to specifying the underlying technology under the assumption of cost minimization. A Cost function can be expressed as follows:

$$C = g(V, p, t)$$  \[4.19\]

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\(^1\) +ve monotonicity requires +ve marginal products for all inputs i.e. the function must be an increasing function of inputs.

\(^2\) This requires, the principal minors of the Boadered- Hessian matrix must have alternative sign, the first being negative.
Where, \( V \) refers to Gross value added and \( C \) refers to total cost, \( p \) is the vector of input prices and \( t \) is time. Taking \( X_i \) as the vector of inputs a set of Cost share equations can be derived as:

\[
S_i = \frac{pX_i}{C} = \frac{\delta \text{Ln}C}{\delta \text{Ln}p_i}, i = 1, 2, \ldots, n
\]

The rate of technical change (\( \nu_t \)) is obtained from:

\[
\nu_t = \frac{\delta \text{Ln}c}{\delta t}
\]

[4.20]

The elasticity of cost with respect to output i.e. \( \nu_{cv} = \frac{\delta \text{Ln}c}{\delta \text{Ln}V} \) is shown as a measure of scale economies (dis-economies).

The bias in technological change for the use of \( i^{th} \) input (\( \nu_{pit} \)) is obtained from:

\[
\nu_{pit} = \frac{\delta \text{Ln}S_i}{\delta t} = \frac{\delta^2 \text{Ln}C}{\delta \text{Ln}p_i \delta t}
\]

[4.21]

Obviously, technological change is Hicks neutral if \( \nu_{pit} = 0 \), input saving if \( \nu_{pit} < 0 \) and input using if \( \nu_{pit} > 0 \), implying that the cost share of corresponding input increases with a change in technology.

The generalized Leontief and Translog cost functions have been very often used in literature for estimating the technical change. Golder (1998) points out that in many studies the cost function has been estimated jointly with factor share (demand) functions to achieve greater efficiency in the estimates. The models in this approach are estimated as a multivariate regression model with jointly distributed disturbances.

**Merits:**

One of the major advantages of the econometric approach is that it provides full information regarding the specified production technology. It also provides information on other parameter of the production function technology along with productivity estimates. Growth accounting/ or Index number approaches
do not provide this additional information. Since the econometric approach is applied on the basis of the data on inputs and outputs, it allows greater flexibility in the specification of the production technology. For example, one can introduce the concept of either Harrod-neutral or Solow-neutral technological progress instead of Hicks-neutral technological progress as assumed by the growth accounting method. It is also possible to verify the assumption of constant returns to scale which is often used in the growth accounting approach (Mawson et al 2003).

Demerits:

Several merits of the econometric approach of measuring productivity also bear some costs with it. The application of this approach sometimes gives rise to the issue of robustness for the estimated parameters. For instance, there may be cases where we may end up getting negative factor income for C-D production function. Under those circumstances, one has to impose prior restrictions on the parameter values. Further, when the numbers of observations are small then prior restriction is imposed for preserving the degrees of freedom. Another, major demerit of this approach is that, it is not easy to understand by everybody and productivity estimates cannot be replicated on a continuous basis (Mawson et al 2003).

However, the econometric approach to productivity measurement should be considered as complementary to growth accounting and index number approaches. The result obtained from econometric method helps in getting richer results along with the growth accounting and index number approaches. In conclusion it can be said that testability of the econometric approach appears as a valuable complement to the non parametric approaches which are the normal tool for productivity estimates (Schreyer et al 2001).
4.3.3. Stochastic Frontier Production Function (SFPF)

The SFPF primarily deals with the estimation of technical efficiency change component of total factor productivity. The estimation of technical efficiency dates back to Farrell (1957). Technical inefficiency could occur through the use of bundles of inputs that were larger than the minimum required to obtain the output. The method is credited to Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeek (1977). It shows how far a Decision Making Unit (DMU) is from efficiency frontier. Efficiency frontier can further be studied either through econometric or non-parametric approach. The econometric approach uses parametric representation of technology along with a two part composed error term. One part of composed error term represents statistical noise and is generally assumed to follow a normal distribution. Other part of the error term represents inefficiency and is assumed to follow a particular one sided distribution. To capture the measurement error upon the frontier, Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeek (1977) included another random error in the model. The model hence is popularly known as stochastic frontier production function. The inclusion of additional distributional random error term in the frontier production function helps to capture the effect of random factors in addition to deterministic components such as labour and capital. Another important advancement to the SFPF model is made by Battese and Coelli (1995), where they attempt to measure the parameters of the factors corresponds to influence the levels of technical inefficiency effects along with the separate components of technical inefficiency change and technical change overtime. The parameters of stochastic production function can be estimated using the maximum likelihood or linear programming method.

**Merit:**

A major advantage of stochastic frontier approach is that the deterministic part of the production function can be generalized easily to allow more sophisticated specifications e.g. to incorporate factor bias in technological change or flexible functional forms.
Demerit:
One of the major problems of stochastic frontier function is that there is no a priori justification for the selection of any particular distribution form of the random error term and the resulting efficiency measures may be sensitive to distributional assumption.

4.3.4. Nonparametric Approaches:
Like SFPF approach, the Nonparametric Approaches are also used basically to decompose the TFPG into its components. Such measure doesn’t require explicit specification of production technology and also to make assumptions of Constant Returns to Scale and the structure of market. The following are some of the widely used nonparametric techniques to measure TFPG and its components.

Malmquist TFP Index:
This approach is one of the popular non-parametric approaches of measuring TFP. The index was first introduced by Malmquist in a consumption context and later by Caves et al. (1982) in the productivity context. Caves et al. (1982) defined Malmquist index as the ratio of two output distance functions. Distance function represents a set of multiple-output multiple-input technology.

Malmquist Index shows that productivity growth is the product of technical efficiency change and technical change. Fare et al. (1994) also estimated the production frontier for a variable returns to scale (VRS) technology and separate scale effect from productivity changes. Fare et al. (1994) illustrated how the distance functions could be estimated using Data Envelopment Analysis (DEA).
Data Envelopments Analysis (DEA):

DEA, also called non-parametric frontier estimation is a linear programming based technique dates back to Farrell (1957). This technique converts multiple output measures into a single comprehensive measure of firm level performance. As developed by Charnes, Copper and Rhodes (1978), Farrell's output-input measure of performance is generalized to multiple outputs and input case by means of a fractional mathematical program, where the ratios' denoting the weighted outputs to weighted inputs (i.e. efficiency ratio for each firm level observation being evaluated is maximized). In this approach, no particular production function is assumed. Instead efficiency (θ) is defined as the ratio of a linear combination of output over a linear combination of inputs. To maximize efficiency weights on inputs and outputs are chosen directly. In case of multiple outputs, outputs would be aggregated linearly. Indominated observations are labeled 100% efficient. Domination is viewed in terms of relative use of same level of weighted input aggregates for producing more of all outputs by another firm or a linear combination of other firms. Each observation requires solving a linear programming problem separately. The efficiency measure θ, can be defined as the productivity differences between unit i and the most productive unit. The notable advantage of DEA is the exclusion of the functional form or behavioral assumptions. The underlying technology remains entirely unspecified and differs across firms DEA optimizes for each individual firm level observation, in place of overall aggregates and the single optimization normally performed in statistical regressions (Seiford et al 1990).

Merits:

The DEA approach doesn't require information on prices and hence suitable when such data, are not available. Besides, this approach allows decomposing productivity growth into technical change and technical efficiency change. Also, in this approach, inferences of dynamic efficiency patterns are feasible.
Demerits:

The flexibility in weighting in this approach has drawbacks as the most widely used implementations are not stochastic, making estimates sensitive to outliers. Because, each observation is compared to all others; measurement error for a single firm can affect the productivity estimates (Biesebroeck 2007).

In this study, we have used the Divisia-Tornqist Approximation under Growth Accounting Approach to measure total factor productivity. The Frontier Production Function Model or other Nonparametric measures though preferable to measure TFPG; they may not be useful in our case as such methods are better suited for estimating efficiency of firms within a given industry. In the present study, we are looking for TFP and its growth in industries but not across firms within an industry.

4.4.1. Empirical Approaches to the Measurement of Output and Inputs

The term 'productivity' shows the technological relationship between factor inputs and output. Thus, the concept is crucially dependent upon the definition of factor inputs & outputs. In fact, it is practically difficult to devise a method of aggregating a host of technologically heterogeneous elements into a single meaningful figure (Banerji 1975). Grilliches (1994) points out that the measurement errors are the single most important problems in estimating productivity.

It is difficult to make a choice between gross output and value added to be used as a measure of output in empirical studies. Gross output can be defined as the ex-factory nominal value of products and by-products manufactured during the accounting year. It also includes the receipts for industrial and nonindustrial services rendered to others. Value added in nominal terms is defined as the value of output produced less the value of intermediate inputs used. It is argued by many that the use of gross output as a measure of aggregate output is not appropriate as it will prone to
differences in the material intensities of various industries as well as its failure to capture the differences in vertical integration within an industry (Kumar 2001). It creates difficulties to add output in the process of aggregation (Griliches et al 1971). In this context, Golder et al (2002) pointed out that the use of gross output function involved double counting and hence inappropriate to consider it as a measure of output. Use of GVA in place of gross output in productivity analysis provides an account for differences and changes in the quality of inputs (Salim et al 1999). Moreover, use of GVA rather than gross output allows comparisons between firms that are using heterogeneous raw materials (Grillich et al 1971). Similarly, the use of gross output in place of GVA necessitates the use of raw materials which may obscure the role of labour and capital in productivity growth (Hosain et al 2004). Filipe (1999) also pointed out the problem of non availability of the measure of aggregate output as a physical quantity empirically. Hence, he was in favour of using real value added as a measure of output in productivity analysis.

**Single Deflation Method (SDM) VS Double Deflation Method (DDM) for Deflating Gross Output/ or GVA:**

Factor productivities should take into account price changes to separate their real contribution from the nominal value added. In literature, there are two district approaches to have the figures of real value added. They are: (i) Single deflation method (SDM) and (ii) Double deflation method (DDM). In regard of single deflation method, both nominal value added components i.e. value of output and value of intermediate inputs are deflated by a single price Index whereas with respect to double deflation method, the nominal value of intermediate inputs is first deflated by the price index for these inputs and then subtracted from the nominal value of output by its price index. Balakrishnan and Pushpangadan (1994) point out that the use of single deflation method is valid only to a situation where price of materials relative to price of output is more or less constant in the period of analysis. Thus, if
the relative price is altering, measured productivity would differ. The total growth of output is the combined effects of primary factors of production namely capital and labour as well as technical progress which itself is depending on change in relative price. If relative price of materials with respect to output price is increasing overtime, the use of SDM would show sluggish growth of TFP. Similarly, in the face of declining relative price of materials, the SDM overestimate the TFP growth. Under such a condition the SDM cannot really be a good measure of productivity growth. Productivity measured on the basis of real value added obtained by SDM is likely to be biased downward (Bruno, 1984). However, in applying DDM with the assumption of 'base year prices are equal to unity' for output and material input is difficult to understand. Central Statistical Organization (CSO 1980), recognizes the DDM theoretically for obtaining real value added, but it has not adopted this method mainly due to data constraints and non-feasibility of the procedure particularly for the non-availability of appropriate price index for materials inputs. As the proper identification of input groups as well as correct weights attached to each such group are not easy to derive, so most of the scholars are in favour of using single deflation method. Dhalokia and Dholakia (1994) have remarked that the double deflation method isn't necessarily superior to the single deflation method. He feels that collection of different sets of prices as well as deriving their weights required for DDM is extremely difficult and hence there is substantial bias involved in the use of double deflation method. As the DDM is more susceptible to fluctuations in the base year and it is rather difficult to change the base year regularly.

Following the difficulties in constructing price indices for inputs by choosing appropriate weights for them at state level, the present study uses SDM to arrive at real gross value added in spite of its limitations. Also, from our above discussion, it is also clear that both the procedures are subjected to limitations and are likely to generate some errors. In Indian context, many authors like Banerji (1975); Ahluwalia (1985, 1991); Golder (1985, 2004); Unel (2003) etc. used SDM in their productivity studies.
Measurement of labour

Labour productivity to an extent depends upon how one measures labour input in productivity study. Denison (1961) laid stress on employment data as a measure of effective labour input. ASI provides a measure of labour input called ‘Number of Workers’. ‘Workers’ are defined as including all persons employed directly or through any agency whether for wages or not and engaged in the manufacturing process or any kind of work incidental to or connected with the manufacturing process. This measure is difficult to use as it doesn’t consider the services of persons other than workers who are as much important for getting the work done as the workers who operate the machines. Golder (1986) points out that ‘man hour’s series’ in the ASI data set covers only workers and leaves out persons other than workers. ASI provides another measure of labour input called ‘number of employee’s series’. Number of employees in the ASI frame includes both workers and persons other than workers. This measure also has limitation because it treats ‘workers’ and persons other than workers’ as perfect substitutes. Most of the Indian studies (e.g. Ahluwalia 1985, 1991; Golder, 1986; Balakrishnan and Pushpangadan, 1991; Rao 1996; Pradhan & Barik 1999 etc.) on Manufacturing Productivity use the number of employees as labour input. Following the studies, in the present study, we have used the number of employee’s series in ASI as a measure of labour input in our study. To get the employees data series since 1998-99, we added the number of workers & employees other than workers for each industry group for every year.

Measurement of Capital Input

The measurement of capital stock is very complicated and has been discussed extensively in literature. Empirical estimates of capital cover two broad aspects (i) measurement in terms of input costs and (ii) measurement in terms of specific contribution of capital to total production (service capital). Like labour, capital possesses several difficult attributes as an object of aggregation. These attributes are longevity, impermanency, technological...
change, future income (Domar 1961). Longevity of capital for different vintage, bought at different prices under different technological conditions makes their aggregation difficult. Impermanency of capital led to their depreciation and replacement problems. Technological change has its impact both on the production and quality of finished products. The quality of capital input is of particular importance because new capital is a major source of technological change in industries where they are used as inputs. In grouping the various types of capital goods, the neoclassical approach assumes competitive economy, perfect foresight that the quality of capital is independent from both relative prices and the distribution of income. It is impossible to construct an index of the quantity of capital; Capital is essentially a value concept that is affected by changes in relative factor prices, the interest and wage rates. Moreover, technological issues are such that different types of machines are complementary; therefore they are not perfect substitutes as required by the neoclassical aggregation principle (Kaldor 1962). Ruggles and Ruggles (1961) discussed the capital measurement difficulties in terms of cost of inputs approach. The production systems are completely different in terms of techniques and relation of production. Capital may be underweighted in terms of returns in comparison to the cost of other capital due to economies of scale though there may be little differences as regard their functions.

According to Benerji (1975), 'Construction of correct price Index for capital goods may be a way to resolve the above disagreement. However, in doing this one has to face another difficult problem regarding the separation of the influences that increase the productivity of capital goods from the ones that increase the productivity in the production of goods. This type of design improvement originating from the changing cost of production requires one to take final decision on differentiating capital goods which in turn based on their functions. Capital items with constant nature of function will only affect the price Index not the quantity of capital. In contrast, if the functions change, the associated changes in costs will change the quantity of capital rather than
the price Index. In such a case, the essential thing to judge is whether it is the same capital item or not after a change in specification has taken place.'

While deflating capital goods one has to face an Index number problem due to technological progress. Technical change makes comparisons of real capital measurement difficult. As such in estimating the net capital stock one has to face difficulties in determining the capital consumption allowances. This measure should include both the actual deterioration in current services generated by the capital item and shorting of the remaining life of it. This involves not only changes in the physical efficiency of capital but also an allowance for future events associated with the changes in the value of capital due to obsolescence. However, a constant ratio between net and Gross Capital stock can be assumed to overcome the above problem. But, in reality the average life of capital-goods will change and hence the ratio between net and gross stock will be altered. Inclusion of dynamic factors into the problem of allocating capital consumption allowances (CCA) overtime becomes a difficult task. Considering the fact that the current flow of services rendered by a capital good is remained to be more or less constant irrespective of its age, some have preferred to use gross capital rather than net capital in empirical studies (Golder 1986). Generally, capital-stock data are used as a proxy for the capital services because of the great difficulties associated with its measurement. Indirect measurement like depreciation rates to derive capital stock may not be out of question because a high rate of depreciation doesn't always mean greater capital input. As such, parameters like rate of use of raw materials, labour services etc. may be included in the production function which show the intensity of the use of capital input. Such measure may provide a better way in assessing the share of capital and hence TFP.

Regarding actual measurement of capital-stock, there are two approaches viz. (i) the replacement cost and (ii) the perpetual inventory method based on book value figure of published data. It is well known that there is no universally accepted measure of capital stock. Besides the theoretical reservations there is also wide differences in the methodology used
An alternative method to replacement cost approach is to derive the discounted value of future income streams. Barna (1957) has preferred to use the replacement cost approach to the alternative method as the later is dependent on short-term waves of expectations. Moreover, on economic ground this replacement cost approach is more acceptable than the ‘discounted future income stream method’ as the former takes into account only the value of capital-employed rather than other difficult attribute such as managerial efficiency. Thus, this concept is much less prone to income than other variables. In many studies capital stock is measured by the book value of fixed assets while in others its flow is measured by summing rent, repairs and depreciation expenses or perpetual inventory created from annual investment data. Each of these measures has its own shortcomings, as for instance, book value and perpetual inventory approach do not address the question of capacity utilization whereas the flow measure may be unrelated to actual depreciation of hardware (Kumar 2006). The widely used Book value measurement approach contains a number of problems as regard their corrections which would need detail information about the existing stock of capital item.

While making an estimate of capital, one has to face the problem of choosing between gross capital and net capital. Use of gross capital over net capital in productivity studies has been preferred by researchers because the depreciation estimates are mainly based on tax based accounting concepts and hence seldom represents actual capital consumption. Banerji (1975) used gross capital stock and warns against the depreciation allowances which are generally used as a proxy for capital services. Gross figures may be more meaningful, with some unknown deduction of a small magnitude than conventional depreciation of existing capital (Hashim and Dadi1973).

Thus, from the above discussion it is clear that there is hardly any universally accepted method of measuring capital stock. However, studies like Hashim
and Dadi (1973), Banerji (1975), Ahluwalia (1991), Golder (1986, 1992) etc. have used a method of capital stock computation which is popularly known as Perpetual Inventory Accumulation Method (PIAM). In the PIAM, capital is measured as the accumulated investment outlay of a number of years at constant prices which may or may not be written down for depreciation. The method is based on the assumption that the stock of capital assets of a certain type consists of gross investment aggregated over the past 1 year where 1 is the assumed normal life of the asset. In empirical works, most of the scholars generally used this method to arrive at the stock of capital (Usher 1981). Here, the initial stock of capital is assumed to be the sum of past investment available. Also, a depreciation rate is assumed here. The method calls for systematic building up of a time series of capital from the book value of same. The increase in real capital of ith type at time t can be computed as: 

\[
\Delta K_t(i) = \frac{I_t(i) + D_t(i)}{P_t(i)},
\]

where \( I_t(i) \) = Time series of net investment at current prices, where subscript t stands for year and i. refers for the type of capital goods, \( P_t(i) \) = Time series of capital goods prices and \( D_t(i) \) = Time series of depreciation. The value of total capital stock of the ith type at time t can be measured as: 

\[
K_t(i) = K_0(i) + \sum \Delta K_t(i),
\]

where, \( K_0(i) \) is the base year value of capital. \( \Delta K_t(i) \) is the additions to K stock at time t. The capital stock series can be obtained by adding this addition of each year weighted by base year prices of capital items. The drawback of this method is that it assumes about a unique and constant life of capital item of given type. However, this method is superior to the ‘blanket deflation procedure’ where the fixed capital stock series obtained from ASI are directly deflated by a price index of capital asset (Golder, 1986). Following Banerji (1975), Roy Chaudhary (1977), Balakrishnan & Pushpangadan (1994), in the present study we also built up the required capital stock series at constant prices using perpetual inventory approach.
4.4.2. Some Empirical Studies on Industrial Productivity in India

A good number of studies are available in literature dealing with productivity changes in the Registered Manufacturing Sector of India at aggregate and at disaggregate levels covering different time periods. An attempt has been made here to provide a brief discussion of some of these studies. Following Golder and Mitra (2002) we would like classify the studies into two groups: (i) studies undertaken till 1992 and (ii) studies undertaken after 1992. Studies based on growth accounting method belonging to the first group include: Hashim and Dadi (1973), Banerji (1975), Ahluwalia (1985, 1991) and Golder (1986, 1992). Using two input and one output framework, most of these studies have taken number of employees as a measure of labour input. The value of gross fixed asset at constant prices obtained by perpetual inventory method (PIM) is taken as a measure of capital input in their studies. These studies mainly use ASI data which is available for 1959 onwards. Studies which covered period before 1959 have used either Census of Indian Manufacturers (CMI) data or combined of both CMI and ASI data. All these works are undertaken on organized industry but these vary in industrial coverage and also size of units covered. A brief summary of the results are presented in table 4.1.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Period</th>
<th>Rate of TFPG (Percent per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banerji (1975)</td>
<td>1946-64</td>
<td>(-)1.6</td>
</tr>
<tr>
<td>Hashim and Dadi (1973)</td>
<td>1946-64</td>
<td>2.8</td>
</tr>
<tr>
<td>Mehta (1980)</td>
<td>1959-70</td>
<td>(-)1.8</td>
</tr>
<tr>
<td>Brahmananda (1982)</td>
<td>1950-80</td>
<td>(-)0.2</td>
</tr>
<tr>
<td>Golder (1986)</td>
<td>1951-65</td>
<td>1.3</td>
</tr>
<tr>
<td>Golder (1992)</td>
<td>1956-84</td>
<td>0.8</td>
</tr>
<tr>
<td>Ahluwalia (1985)</td>
<td>1959-79</td>
<td>(-)0.4</td>
</tr>
<tr>
<td>Ahluwali (1991)</td>
<td>1959-85</td>
<td>(-)0.4</td>
</tr>
</tbody>
</table>

Source: Golder & Mitra (2002)
It is clear from the table 4.1 that there is divergence in results from one study to another even though the study periods overlap or coincides. For instance, while Hashim and Dadi (1973) found a significantly positive rate of TFPG, Banerji (1975) obtained a significantly negative rate of TFPG for the same period of study. Similarly, while Golder (1986) obtained a positive TFPG rate of 1.3% per annum for the period 1951-65, Ahluwalia (1991) found a negative TFPG rate of (-0.4%) for the period 1959-79. The main cause of divergence in results is the difference in methodology and industrial coverage used in these studies. Similar findings have also been observed in the studies on productivity of manufacturing sector during the 1980s which are shown in table 4.2.

Table 4.2: TFP Growth Rate of Indian Manufacturing

<table>
<thead>
<tr>
<th>Authors</th>
<th>Method of deflation</th>
<th>Period</th>
<th>Rate of TFPG (Percent per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahluwalia (1991)</td>
<td>VASDM</td>
<td>1965-79</td>
<td>(-0.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1980-85</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1986-90</td>
<td>5.01</td>
</tr>
<tr>
<td>Balakrishnan &amp; Pushpangadan (1994)</td>
<td>VASDM</td>
<td>1980-88</td>
<td>2.02</td>
</tr>
<tr>
<td></td>
<td>VADDM</td>
<td>1980-88</td>
<td>(-1.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1970-82</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1982-88</td>
<td>(-1.1)</td>
</tr>
<tr>
<td>Dholakia &amp; Dholakia (1994)</td>
<td>VADDM</td>
<td>1980-88</td>
<td>2.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1982-92</td>
<td>(-1.23)</td>
</tr>
<tr>
<td>Mohan Rao (1996)</td>
<td>VASDM</td>
<td>1973-80</td>
<td>(-0.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1981-92</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>VADDM</td>
<td>1973-80</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1981-92</td>
<td>(-0.2)</td>
</tr>
<tr>
<td></td>
<td>GOF</td>
<td>1973-80</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1981-92</td>
<td>(-2.2)</td>
</tr>
</tbody>
</table>

Source: Golder & Mitra (2002)
VASDM = Value Added by Single Deflation Method, VADDM = Value Added by Double Deflation Method, GOF = Gross Output function using Labour, Capital and Materials as inputs.

The table 4.2 shows that evidence in India as brought out by a number of studies has been quite varied. Ahluwalia (1991) who based her study on
value added deflated by the single deflation method found that there was a 'turn around' in TFPG during 1980s with its rate of 3.4 percent per annum during 1980-85 as compared to -0.3% per annum during 1965-79. Balakrishnan and Pushpangadan (B-P) (1994) however demonstrated that such a 'turnaround' in productivity growth is confirmed only when the estimates are derived by using the value added series deflated by single deflation technique. They showed that TFPG is positive (2.02% per annum) for the period 1980-88 as per under value added with single deflation method, while it is negative (-1.1%) as per under value added with double deflation method. Dholakia and Dholakia (1994), however pointed out that B-P study covers only the registered manufacturing sector but they use the input output table for the entire manufacturing sector which includes the unregistered manufacturing sector also. This causes inappropriate weights for input groups in the study of B-P. They showed that if one computes the appropriate weights for the input groups even though by using value added with double deflation procedure, the rate of TFPG comes out to be positive (2.86% per annum) for the period 1980-88. Using gross output function, Das (2006) found TFPG rate to be only 0.08% per annum for the period 19981-2000.

Apart from the above studies there were quite a few studies of productivity undertaken by using econometric approaches. Krishna and Mitra (1998) conducted a study using firm level panel data obtained from Centre for Monitoring Indian economy (CMIE) and observed a high productivity growth during 1986-1993 of electrical machinery, non-electrical machinery and electronics after 1991. A study by B-P (2000), which employed the same methodology as that of Krishna and Mitra however shows a significant fall in the productivity growth rate after 1991. A study by Mitra (1998) based on estimation of frontier production function reported that TFPG for the Manufacturing Sector in India was higher for the period 1985-86 to 1993-94 (5.57% per annum) than that for 1976-77 to 1984-85 (0.47% per annum).

Ray (2002), using nonparametric approach (Malmquist Index) in his study has observed an increase in the rate of TFPG from 0.17% per annum during
pre-reform era (1990-91) to 1.45% per annum during post reform era. Using Malmquist Index, Kumar (2006) also found a similar direction in TFPG rate (1.7% per annum during 1982-83 to 1990-91 and 3% per annum during post 1990-91 periods) for the Indian organized manufacturing sector. The difference in magnitude of estimated growth rates of TFP may be due to orientation of methodology. While Ray uses the output orientation in the measurement of Malmquist Index, Kumar Surendra employs input distance functions in measuring TFPG.

So far in Assam, no study dealing specifically with industrial production & productivity in details has seen to be undertaken. However, Awasthi (1975) undertook a work on the economics of tea industry in India with special reference to Assam. The study analyzed the growth of tea plantation and manufacturing along with export promotion measures of tea industry in Assam. Baruah (1987) used production function framework to estimate the returns to scale and elasticity of substitution parameters of 12 selected manufacturing industries of Assam using ASI data for the period 1966-79. Neog (1988) analyzed the role of industry in economic development of NE region and attempted to study the sectoral interdependence of the national & regional economy by using econometric techniques and suggested for resource based industrialization for the North East region. Goswami (1981) analyzes the role of three industries in Assam viz. tea, oil refining and plywood and contends that the petro chemical industry would be capable of contributing to the diversification of the state economy.

4.5. The broad conclusions that can be drawn from this discussion are as follows

- Aggregation has proven itself to be the most challenging task for productivity estimate which affects the magnitudes, the stability and the dynamic changes of total factor productivity.
- The different methodologies used to measure TFP have their own advantages and disadvantages and therefore researchers are attempting to use a particular methodology depending on their
purposes of inquiry. However, owing to the advantages attributed to the Growth Accounting Approach using either translog production or cost function, it has been preferred by most of the researchers for analyzing industry level productivity growth. The SPF model and Non parametric Approach using either Malmquist Index or DEA are another two widely used approaches in present time for measuring the efficiency component of TFPG across industries.

- The measurement issues pertaining to inputs particularly the capital input for its endogeneity nature in the production process is still recognized as a serious problem in literature. Aggregation bias in this context should have considerable importance to isolate the pure residual. Regarding output measurement, most of the studies though well recognized the effect of changing relative prices on output growth yet they have used value added with single deflation method as a measure of output following the practical difficulties in using the double deflation method.

- The study on the TFPG growth rates of Indian Manufacturing sector as observed from the above cited works gave contradictory results. This may however be due to differences in coverage of industries, period of analysis, methodology used and measurement of capital stock. The survey of relevant literature also reports that the rate of TFPG was lower in the 1970s than that in the 1980. However, there has been an increase in TFPG in post 1991 years.