CHAPTER 1

INTRODUCTION
1. INTRODUCTION

1.1 GENERAL INTRODUCTION

A major source of Economic growth, apart from inputs growth was identified as technological advancement. The contribution of technical change to output growth has been obtained as residual.

For a long time, in empirical economics, technical change and total factor productivity were treated alike. Total factor productivity may be defined as the output per unit of combined inputs foregone during the course of production

$$ TFP = \frac{u}{F} $$

Where

$ TFP $ : Total factor productivity

$ u $ : Observed output

$ F $ : Input index

Total factor productivity growth may be expressed as follows:

$$ \frac{\dot{TFP}}{TFP} = \frac{\dot{u}}{u} - \frac{\dot{F}}{F} $$

$$ \Rightarrow \frac{\dot{u}}{u} = \frac{TFP}{TFP} + \frac{\dot{F}}{F} $$

$$ \text{..... (1.1.1)} $$

Where

$$ \frac{\dot{x}}{x} = \frac{dx}{dt} = \frac{d \ln x}{dt} $$

Technical change refers to advances in knowledge in relation to art of production.

1.2 STATEMENT OF THE PROPOSED STUDY

One of the basic tools to measure technical change is Shephard’s output distance function defined as the ratio of observed output to potential output. The benchmark to measure potential output is the data envelopment frontier determined by the best practice production units, which in the language of Data Envelopment Analysis (DEA) are called Decision Making Units (DMUs). The envelopment surface is obtained under a set of axioms, viz., (i) the convexity axiom (ii) free disposability of inputs and outputs and (iii) minimum extrapolation. The envelopment surface so obtained admits variable returns to scale.

The introduction of one more axiom, namely, ray unboundedness spins cone technology that admits constant returns to scale alone**.

The total factor productivity index as suggested by Malmquist*** can be expressed in terms of output distance functions evaluated under the technologies of two consecutive time points.

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The Malmquist total factor productivity change can be decomposed into the product of technical and efficiency changes. The output technical efficiency is measured by the ratio of observed to potential output. To compute output technical efficiency we use as benchmark the envelopment surface of the cone technology.

The decomposition of Malmquist TFP index change into the product of technical and technical efficiency changes imply that TFP change and technical change are one and the same provided that the DMU is 100 per cent output technical efficient.

Further, output technical efficiency can be multiplicatively decomposed into output pure and scale efficiencies. Consequently, the technical efficiency change can be expressed as product of pure technical and scale efficiency changes.

\[ \text{TFP change} = \text{Technical change} \times \text{Efficiency change} \]

\[ \text{Technical Change} = \frac{\text{TFP Change}}{\text{Efficiency Change}} \]

The output distance functions involved in the definitions of TFP, Technical and Efficiency changes can be obtained by solving suitably structured linear programming problems. The Malmquist total factor productivity and its constituent components require inputs and outputs of decision making units.
The accounting approach used in this study to measure technical change requires the decision making unit (DMU) in focus is cost minimizer and the process requires not only data on inputs and outputs, but also input and output prices.

The method decomposes TFP growth into the sum of growth rates of technical change, pure technical, scale, allocative efficiencies. As such, the Malmquist TFP decomposition and accounting decomposition will not give identical results.

\[
\begin{align*}
\text{TFP} &= \hat{TC} + \hat{PTE} + SE + AE \\
\text{TFP} &= TC + PTE + SE + AE \\
\frac{\hat{TC}}{TC} &= \frac{\text{TFP}}{TFP} - \frac{PTE}{PTE} - \frac{SE}{SE} - \frac{AE}{AE} \\
\end{align*}
\]

\[\text{..... (1.2.1)}\]

Moreover, the pure technical, scale and allocative efficiencies used in TFP growth decomposition are all input based. If returns to scale are constant, the output based Shephard’s distance function is inverse of the input based distance function. However, in general, the output based pure technical and scale efficiencies need not be equal to their input based counter parts.

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Basically, the output growth can be decomposed into the sum of rates of growth of inputs represented by an input index, input pure technical, scale and allocative efficiencies.

\[
\frac{\dot{u}}{u} = \frac{\dot{F}}{F} + \frac{PTE}{PTE} + \frac{SE}{SE} - \frac{AE}{AE} .... (1.2.2)
\]

Where

\[
\frac{\dot{F}}{F} = \sum_{i=1}^{n} \frac{\dot{x}_i}{x_i} .... (1.2.3)
\]

\[
s_i \text{ is } i^{th} \text{ input cost share}
\]

\[
\sum_{i=1}^{n} s_i = 1
\]

\[
X_i \text{ is } i^{th} \text{ input of production}
\]

The time axis of sample period 1985-1998 is divided into 3 time epochs, 1985-89, 1989-93 and 1993-97. Four production possibility sets are constructed with linear technology which are expected to satisfy the inclusion property.

\[
S(t) \subseteq S(t+1)
\]


\[
S(t) = \{ (x, u) : \sum_{i=1}^{k} \lambda_i x_i \leq x, \sum_{i=1}^{k} \lambda_i u_i \geq u, \lambda_i \geq 0 \}
\]

Where \( x_i \in \mathbb{R}^n \).

\( x_i \in \mathbb{R}^n \), are the input vector and output of \( i^{th} \) DMU. It is hypothesized that K DMU's are in competition.
To understand the difference between input and output efficiencies, first consider an input level set:

\[ L(u) = \{ x : x \text{ produces } u \} \]

\[ L(u) \]
\[ L^v(u) \]
\[ (x^0_1, x^0_2) \]

Fig. 1.1

\[ L(u) \text{ is input level set of variable returns to scale envelopment surface. } L^v(u) \text{ is input level set of constant returns to scale frontier.} \]

\[ L(u) \subseteq L^v(u). \]

The producer who operates at P is pure technical inefficient. By reducing inputs radially from P to Q, the DMU can attain 100 percent pure technical efficiency. Input pure technical efficiency is obtained by solving the following optimization problem.

\[ \left[ D_i(u,x) \right]^{-1} = \min \{ \lambda : \lambda x \in L(u) \} = \text{PTE} \]

where \( D_i(u,x) \): is input distance function

\[ PTE: \text{Pure technical efficiency} \]

Further reduction of inputs from \( Q \) to \( R \) leads to 100 per cent scale efficiency. The DMU attains overall technical efficiency by reducing its inputs from \( P \) to \( R \). The input overall technical efficiency can be obtained by solving the following optimization problem.

\[
\left[ D_i^t(u,x) \right] \Rightarrow \min \left\{ \lambda : \lambda x \in L_i^t(u) \right\}
\]

Where \( D_i^t(u,x) \) is the input distance function of cone technology.

\[
L(u) \subseteq L_i^t(u) \Rightarrow \left[ D_i(u,x) \right]_{-} \geq \left[ D_i^t(u,x) \right]_{-}
\]

\[
\Rightarrow D_i(u,x) \leq D_i^t(u,x)
\]

The ratio \( \frac{D_i(u,x)}{D_i^t(u,x)} \) measures input scale efficiency (ISE).

\[
ISE = \frac{OR}{OQ} = \frac{D_i(u,x)}{D_i^t(u,x)} \quad \ldots \quad (1.2.4)
\]

The producer who operate at \( R \) is only input overall technical efficient. The point \( R \) is not cost efficient. By reallocating his inputs from \( R \) to \( T \) he can attain allocative efficiency. Since \( T \) is cost efficient point, the cost efficiency (CE) is defined as,
\[
CE = \frac{OS}{OP} = \frac{Q(u,p)}{p_1x_1^p + p_2x_2^p} \quad \ldots \ldots (1.2.5)
\]

The numerator is factor minimal cost function, expressed as an optimization problem:

\[
Q(u,p) = \min \{px : x \in L^k(u)\}
\]

The denominator is cost of P

Input allocative efficiency (IAE) is the ratio,

\[
IAE = \frac{OS}{OR} = \frac{OS}{OP} \times \frac{OP}{OR} = CE/OTE \quad \ldots \ldots (1.2.6)
\]

\[
\Rightarrow CE = OTE \times IAE = PTE \times ISE \times IAE \quad \ldots \ldots (1.2.7)
\]

Where OTE is the output technical efficiency.

In the accounting approach to measure technical change the optimization problems formulated above are solved to find PTE, CE, AE, OTE and SE for time period \( t = 1985, 1989, 1993, 1997 \).

To implement Malmquist total factor productivity and to measure technical change output distance functions are to be computed.
The output level set $P(x)$ is defined as$^*$,

$$P(x) = \{u : u \text{ is produced by } x\}$$

There is duality between the input and output level sets.

$$P(x) = \{u : x \in L(u)\}$$

$$L(u) = \{x : u \in P(x)\}.$$  

$P(x)$ and $P^k(x)$ are output level sets consisting with variable and constant returns to scale respectively.

The DMU that operates at $P$ is output pure technical inefficient (OPTE) By radially expanding inputs from $P$ to $Q$, the DMU attains output pare technical efficiency.

$$\text{OPTE} = \frac{OQ}{OP}$$

Fare, R.C., et.al (1985), op.cit.
OPTE can be estimated by solving the following optimization problem:

$$\left[D(x,u)\right]^{-1} = \text{Max} \left\{ \theta : \theta u \in P(x) \right\} = \text{OPTE}$$

A further expansion of outputs from P to Q leads to scale efficiency. The product of OPTE and OSE gives output overall technical efficiency (OOT). 

$$\text{OOT} = \text{OPTE} \times \text{OSE} \quad \ldots \quad (1.2.8)$$

$$\text{OOT} = \left[D_0^k(x,u)\right]^{-1} = \text{Max} \left\{ \theta : \theta u \in P^k(x) \right\}$$

$$P(x) \subseteq p^k(x) \Rightarrow \left[D_0(x,u)\right]^{-1} \leq \left[D_0^k(x,u)\right]^{-1}$$

Where $D_0(x,u)$ and $D_0^k(x,u)$ are Shephard's output distance functions under variable and constant returns to scale respectively.

$$D_0(x,u) \geq D_0^k(x,u)$$

The ratio $\frac{D_0(x,u)}{D_0^k(x,u)}$ measures output scale efficiency.

The input and output distance functions, under constant returns to scale are inversely related.

$$\left[D_0^k(x,u)\right]^{-1} = \text{Max} \left\{ \theta : \theta u \in P^k(x) \right\}$$

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\[
\begin{align*}
&= \max \{ \theta : x \in \overline{\mathcal{E}} \mathcal{L}^k(u) \} \\
&= \max \left\{ \theta : \frac{x}{\theta} \in \mathcal{L}^k(u) \right\} \\
&= \max \left\{ \lambda : \lambda x \in \mathcal{L}^k(u) \right\} \\
&= \min \left\{ \frac{1}{\theta} : \frac{x}{\theta} \in \mathcal{L}^k(u) \right\} \\
&= \min \left\{ \lambda : \lambda x \in \mathcal{L}^k(u) \right\} \\
&= D^k_\theta (u, x) \\
\therefore [D^k_\theta (x,u)]^\top &= D^k_\theta (u, x) \quad \text{.....(1.2.9)}
\end{align*}
\]

1.3 OBJECTIVES OF THE STUDY

The main objective of the proposed study is to measure technical change by using two approaches namely the distance function approach and the accounting approach. The former method is based upon the linear programming technique and time series data on inputs and outputs. The accounting approach hypothesizes cost minimization, and makes use of time series data on inputs, outputs and input prices.

In the present study the total manufacturing sectors of 14 Indian States which account for 85 per cent of the country's total value added each State is a DMU. The sample time period across

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* If returns to scale are constant, it can be shown that \( L^k (\theta u) = \theta L^k(u) \), which is not true if returns to scale are either increasing or decreasing.
which technical change is measured covers the period from 1985-1998.

The fourteen DMUs are the total manufacturing sectors of

(i) Andhra Pradesh  (ii) Bihar  (iii) Gujarat
(iv) Haryana  (v) Karnataka  (vi) Kerala
(vii) Madhya Pradesh  (viii) Maharastra  (ix) Orissa
(x) Punjab  (xi) Rajasthan  (xii) Tamilnadu,
(xiii) West Bengal  (xiv) Uttar Pradesh.

1.4 DATA FOR EMPIRICAL INVESTIGATION

The data are secondary*, gathered from Annual Survey of Industries (ASI), covering the period from 1985-1998.

The sample period is divided into three epochs:

Epoch-I  1985-86 to  1989-90
Epoch-II  1989-90 to  1993-94
Epoch-III  1993-94 to  1997-98

1.5 VARIABLES UNDER STUDY

The different inputs and output variables used under the present study are

i. Net Value added, a proxy for output,

ii. Total persons engaged, a proxy for labour input,

iii. Fixed capital, and

iv. Wages and Salaries.

There are two more derived variables viz., (v) Wage rate (vi) Rate of return on capital.

\[
\text{Wage rate (w)} = \frac{\text{Wages and salaries including employers contribution}}{\text{No. of persons employed}}
\]

\[
\text{Rate of return (r)} = \frac{\text{Value added - Wages and Salaries}}{\text{Fixed capital}}
\]

The money values are deflated by suitable deflators, expressed at constant prices of 1985-86.

Definitions of the variables:

i. **Net Value Added (u):**

Deducting total input value and depreciation from total output value added is computed.

ii. **Total persons engaged (L):**

Number of persons include the employees and all working proprietors and their family members who are actively engaged in the work of the factory even without any pay and the unpaid members of the co-operative societies who worked in or for the factory in any direct and productive capacity.
The number of workers or employees is an average number obtained by dividing Mondays worked by the number of days the factory had worked during the reference year.

iii. **Fixed Capital (k):**

Fixed Capital represents the depreciated value of fixed assets owned by the factory as on the closing day of the accounting year. Fixed assets are those which have a normal productive life of more than one year.

Fixed capital includes land including lease hold land, buildings, plant and Machinery, furniture and fixtures, transport equipment, water system and roadways and other fixed assets such as hospitals, schools etc. used for the benefit of factory personnel.

iv. **Wages and Salaries (w):**

Wages and Salaries are defined to include all remuneration in monetary terms and also payable more or less regularly in each pay period to workers as compensation for work done during the accounting year. It includes (a) Direct wages and salary, (b) Remuneration for the period not worked, (c) Bonus and ex-gratia payment.
1.6 ORGANIZATION OF THE STUDY:

The organization of study itself reveals how the objectives of the study have been achieved within the described framework.

Chapter-I is an introductory one. It contains the general introduction about the measurement of technical change in terms of total factor productivity growth and the contribution inputs growth to output growth, besides the statement of the proposed study and main objectives of the study. It also gives the definitions of different variables under study along with the organization of the present study.

Chapter-II deals with the review of literature about the measurement of technical change. In this chapter three important approaches namely, Parametric, Non-Parametric and Accounting approaches have been discussed for the measurement of technical change and technical progress. Beside these the concept of technical change and technical progress have also been introduced.

Chapter-III proposes some theoretical methods to decompose the Malmquist total factor productivity index into different efficiency changes. The measures for input and output efficiency changes have been separately explained in this chapter. Hicks Neutral and Non-neutral technical change measures are also presented along with capacity utilization and factor minimal cost function. A non-parametric approach for technical change based on cost function has been discussed.
Chapter IV presents the empirical investigation regarding the present research study. The various efficiency changes such as pure technical, output technical, scale efficiency changes have been completed for different states in India for the study periods namely, epoch-I: 1985-86 to 1989-90, epoch-II: 1989-90 to 1993-94 and epoch-III: 1993-94 to 1997-98. The empirical data have been collected from the issues of Annual Survey of Industries (ASI), Govt. of India, New Delhi.

Chapter V depicts the summary of results and important conclusions of the present work. It also gives the comparison of the results obtained from Malmquist and growth accounting approaches. Various selected references regarding present study have been given under a separate title "Bibliography".

1.7 Chapter Scheme:

The contents of the present research work are presented under the following heads:

CHAPTER-I - Introduction

CHAPTER-II - Review of Literature

CHAPTER-III - Theory and Methodology

CHAPTER-IV - Empirical Investigation

CHAPTER-V - Summary and Conclusions