CHAPTER-9:
ECONOMETRIC MODEL ANALYSIS

9.1. Economic development and productivity growth
9.2. Meaning and measurement of productivity growth
9.3. Productivity growth and technological changes
9.4. Technology and technological changes
9.5. Production function and productivity growth
9.6. Partial and Single factor productivity
9.7. Total factor productivity
9.8. Total productivity and Total factor productivity
9.9. Approach to measurement of productivity growth
9.10. Analysis of factor productivity and factor efficiency
9.11. Analysis of efficiency of labour
9.12. Analysis of labour and capital productivity with Spline function
9.13. Analysis of Total factor productivity
9.15. Solow Index
9.16. Translog Index
9.17. Empirical findings
9.18. Parametric Approach
9.20. Observation
9.21. Validity of Verdoorn law
9.1. Economic development and productivity growth:

“Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use. While there is no disagreement on this general notion, a look at the productivity literature and its various applications reveals very quickly that there is neither a unique purpose for nor a single measure of productivity.”

(Paul Schreyer
OECD Statistics Directorate
OECD PRODUCTIVITY MANUAL, 2001)

“The two main sources of economic growth in output are increases in the factors of production (the labour and capital devoted to production) and efficiency or productivity gains that enable an economy to produce more for the same amount of inputs.”

(Baldwin, Harchaoui, Hosein and Maynard, 2000
“Productivity: Concepts and Trends”
Statistics Canada)

Productivity growth is the basis of efficient economic growth. Economic growth has been defined as the process of a sustained increase in the production of goods and services with the aim of making available a progressively diversified basket of consumption goods to population. Scarcity of resources has been recognised as a limiting factor on the process of economic growth. While output expansion based on increased use of resources is feasible, it is not sustainable. Therefore, efficiency or productivity of resources becomes a critical factor in economic growth. These terms, which will be defined more precisely in the following section, indicate ability to obtain a given amount of output by using a lesser amount of input. Productivity growth, therefore, is critical for ensuring sustained increase in the production.

Economic growth has traditionally been associated with industrialisation. At least that is what makes the diversity in the basket of consumption goods and services possible, when trading possibilities are limited. But industrialisation in the initial
stages has the effect of making resource scarcities more acute, making it all the more necessary that available resources are utilised more productively.

Role of productivity growth in the process of economic growth became clear when in the 1950's it was found that accumulation of productive factors (capital and labour) could explain only a fraction of actual expansion of output. Empirical work on the American economy by Tinbergen (1942), Schmookler (1952), Fabricant (1954), Abramovitz (1956), Kendrick (1957), Solow (1957) and Denison (1962) showed that between 80 to 90 percent of observed increase in output per head could not be explained by increase in capital per head and was attributed to productivity growth. Further, Terleckyi (1974), Scherer (1982, 1987) and Griliches (1984) showed that technological advancement was a major source of productivity improvement for the American industry.

Productivity growth in the manufacturing sector in general and steel industries in particular has the effect of modernisation. The degree of this modernisation of course depends on magnitude and the nature of technological change. If technological change is neutral, in the sense that it affects all inputs equally, the degree of modernisation will depend on the overall growth of technological progress.

9.2 General Concept of Productivity

Productivity is a relationship between production and the means of production. Or, more formally a relation of proportionality between the output and inputs which are used to generate that output. This relationship is articulated through the given technology of production.

9.3 Productivity Growth and Technological Change

Productivity growth is crucially affected by technological change. Their relationship is so close that the two terms often tend to be used interchangeably. Productivity is a wider concept. Even though a crucial one, technological change is only one of the many factors which affect productivity growth. Other being social, cultural, educational, organisational and managerial factors. Better management of
workers and machines and appropriate incentive structures can increase production and/or reduce costs. But these are different from technological change.

9.4. Technology and Technological Change

At this stage the question is what does technological change mean. A prior question is what is technology? Unfortunately, there is no simple answer to this question. Marjit and Singh (1992) have explored various aspects of this question. We confine ourselves to one directly relevant for our study. In the standard neo-classical economic model technology refers to a collection of techniques, or ways of specifying how much of various outputs can be produced using given quantities of various inputs. In most textbook situations this is simplified as a single output production function which specifies the maximum quantity of output predicable from given quantities of labour and capital. Technology is then the production function. It is generally represented graphically with the help of level curves or isoquants. Technological progress in this simple framework is a shift upwards of the production function, or shift downwards of the representative isoquant.

An alternative way is to look at cost functions which relate levels of cost of production to level of output and to factor prices. In many situations cost functions are easier to characterise production functions. The data for cost functions is more easily available. Given input prices, one can view technological improvement as a downward shift of the cost function.

Technology has two aspects, ‘embodied’ or ‘disembodied’. The former is identified with ‘hardware’ and consists of tools, machinery, equipment and vehicles, which together make up the category of capital goods. Disembodied technology is identified with ‘software’ and encompasses the knowledge and skills required for the use, maintenance, repairs, production, adaptation and innovation of capital goods. These are often called the ‘know-how and the know-why of processes and products’.

Technological change does not necessarily affect all factors equally. When it does, it is considered neutral technical change. Otherwise, it may have a specific factor using or factor saving bias. The terms technological change and technical
change are used interchangeably in the literature under review, both being indicators of a shift in the production function. It would have been useful to reserve the latter term for indicating change in techniques or processes. The terms technological progress and technical progress are synonymous with technological change and technical change respectively, all change being considered as being for the better.

9.5 Production Function and Productivity Growth

As indicated above, the notion of a production function is central to the meaning of technology. It is consequently crucial for the measurement of productivity. A production function is a technological relationship which specifies the maximum level of output of a good which can be obtained from a given level of one or several inputs.

In its general form a two input production function can be written as

\[ Y_t = f(K_t, L_t) \]

Where,

- \( Y_t \) = level of net output (value added).
- \( K_t \) = capital input (or service of factor capital)
- \( L_t \) = labour input
- \( t \) = time

9.6 Partial or Single Factor Productivity

The partial or single factor productivity (PP) of labour or capital is indicated by the ratio \( Y/L \), or \( Y/K \) i.e. output per unit, or the average product of the factor concerned. The productivity defined this way is merely the inverse of factor intensity. An increase in this ratio, other things remaining the same, implies an increased efficiency of input use, whereby, the same level of output can be produced by a smaller quantity of given input. However, when other things cannot be assumed to be the same, the interpretation of these output factor ratios as indicators of productivity becomes problematic. For example, an increase in labour productivity may only reflect capital deepening - a rise in the \( K/L \) ratio. In such cases it becomes necessary to compute total factor productivity.
9.7. Total Factor Productivity

Total factor productivity (TFP) extends the concept of single factor productivity such as output per unit labour or capital to more than one factor. Thus TFP is the ratio of gross output to a weighted combination of inputs. For the case of production function shown above, TFP at time \( t \) would be given by:

\[
A_t = \frac{Y_t}{g[\alpha K_t, \beta L_t]}
\]

Where

- \( A_t \): Index of TFP at time \( t \).
- \( g \): the aggregation procedure implicit in the specific production function adopted.
- \( \alpha, \beta \) are appropriate weights.

Different functional forms of the production functions imply different aggregation procedures or weighting schemes for combining factor inputs.

9.8. Total Productivity (TP) versus Total Factor Productivity (TFP)

At this stage, choice exists in regards to the specification of output as value added as in equation (1) above or gross value of output. In the latter case, material and energy inputs are explicitly accounted for in both the left and the right hand sides in the production function.

This would give rise to the following general functional form which in recent years has come to be known as KLEM type production function.

\[
y_t = f(K_t, L_t, E_t, M_t, t)
\]

Where,

- \( y_t \): level of gross output per unit of time,
- \( K_t \): capital input (or service of factor capital)
- \( L_t \): labour input
- \( E_t \): input of energy,
- \( M_t \): material inputs.
- \( t \): time
The choice between one form or the other depends on what one believes to be the correct measure of output. It also depends on whether one believes the production function to be separable in factor and material inputs or not.

The above functional forms give rise to alternative concepts of productivity. One can define the productivity measure associated with the value added (V) production function as total factor productivity (TFP) and that associated with gross output (Y) production function as total productivity (TP).

In the survey which follows it will be seen that the majority of studies have been conducted using production functions with value added as output and with K and L as inputs. It is only recently that studies on production functions in India have been using gross output and K, L, E and M as inputs.

9.9. Approaches to the Measurement of Productivity Growth

There are three principal approaches to measurement of productivity growth. These are: (i) The index number approach, (ii) Parametric approach and (iii) Non-parametric approach.

In the present survey we focus primarily on studies which have estimated productivity growth using the first approach. Wherever appropriate, the results from the estimation of cost and production functions have been mentioned in support of as alternative explanations to the results of the first approach. The non-parametric approach which is based on linear programming models of relative efficiency is not reviewed here.

Index Number Approach

In this approach the observed growth in output is sought to be explained in terms of growth in factor inputs. The unexplained part or the residual is attributed to growth in productivity of factors. It consists in assuming a certain functional form for the producers' production function and then deriving an index number formula that is
consistent (exact) with the assumed functional form. Preferred functional forms are the flexible ones. These indices differ from each other on the basis of underlying production function or the aggregation scheme assumed. Following indexes are used in this study.

- Kendrick Index
- Solow Index
- Translog Index

**Parametric Approach**

Parametric approach consists in econometric estimation of production functions to infer contributions of different factors and of an autonomous increase in production over time, independent of inputs. This latter increase, which is a shift over time in the production function, can be more properly identified as technological progress. It is one of the factors underlying productivity growth. An alternative to estimation of production functions is estimation of cost functions using results from the duality theory. These are the commonly used specifications of production functions.

- Cobb-Douglas Specification
- Constant Elasticity of Substitution (CES) Specification
- Transcendental Logarithmic (TL) Specification

**9.10. Analysis of Factor Productivity & Factor efficiency:**

If we want to ascertain some of the causes of stagnation or slowdown and acceleration of growth in Indian steel industry, probably it shall not be a bad idea to look at the behaviour of the partial factor productivity measurers like labour and capital productivity indices since they reflect the efficiency of single factor input. Moreover, after liberalization, massive modernization took place in Indian Steel Industry. Technology has changed from labour intensive to capital intensive. Therefore, the productivity and efficiency in single factor input (mainly in the primary factor i.e. labour & capital) requires a careful analysis. At the same time productivity & efficiency of the factor before & after liberalisation, is the most important aspect to be considered.
In the present content we categories the major variables as output, labour, capital, emolument, productivity of labour, productivity of capital, and an index total factor productivity (in Solow Index). But there are lot of conceptual difficulties regarding what we want to denote by such terminologies. In other words, the definitions as well as measurement of these variables pose serious problems.

However certain way out is there. For instance we take output measured in term of Gross Value Added (GVA). Some economists also suggest the concept of net value added. But since capital consumption allowance (to be deducted from GVA) is set arbitrarily by income tax authorities, there are some sound ground in considering GVA as our measure of output. Now since the data are expressed in current prices for over twenty four years, so a meaningful analysis calls for translating these figures in terms of some singular base year prices so as to allow for correction of any possible change in the prices over the years under study. For this purpose the index no. of wholesale prices are collected from RBI Bulletin. However, we have started our analysis from the year 1980 - 81, the method of base shifting has been applied in order to make the index of 1981 - 82 as 100, and prices for successive years were changed accordingly with respect to this new shifted base. The figures expressed in current prices henceforth deflated by the corresponding year’s index for prices in order to relate them to the common base 1981 – 82. Figure thus derived yield themselves to easy & meaningful comparison.

Concerning the measurement of labour input in the present work, we use ‘employees’ as the measure of labour input. Of course labour input can be measured by two other alternatives, e.g. ‘workers’ and ‘man-hours’. However, ‘employees’ is a more general term and is inclusive of the concept of workers and persons other than workers. Both of these categories of persons have something to offer in the continuous process of production. Denison (1961), disfavours taking man-hours as a measure of labour-input. He points out that a reduction in man-hours per week leads to an increase in labour input per hour. Thus by measuring labour by number of persons engaged is more satisfactory, because it gets crudely adjusted for one from of quality change, namely the change in the quality of one hour’s work that is due to shortening of hours. Moreover, computation of man-hours in census of Indian
manufactures (CMI) and Annual Survey of Industries (ASI) has been done by multiplying the no. of workers in a shift by eight and then aggregating these products across factories. However, attention is not paid whether the hours allocated to each shift is actually worked or not.

Defining thus labour in terms of total persons engaged, we define labour productivity in terms of GVA and employment ratio.

This part of the analysis is divided into two sub-sections. Section-I provides the methodological framework used for analysing the inter-temporal variations in partial factor productivity indices of labour & capital inputs. In Section-II, empirical results have been presented. In addition, this section looks into the main factors influencing the variations in the labour productivity growth.

Section – I

*Inter-temporal Variation:*

In present study, labour & capital productivity indices have been compute to assess the efficiency of individual factor inputs before and after economic liberalization. The index of labour productivity at time ‘t’ is defined as a ratio of index of output to index of labour input. Symbolically, it can be expressed as:

\[
LP(t) = \frac{Q(t)}{L(t)} \quad (1.1)
\]

Where,

- \(LP(t)\) = Index of labour productivity at time ‘t’
- \(Q(t)\) = Index of output at time ‘t’ (expressed in base year price)
- \(L(t)\) = Index of labour at time ‘t’

On the same lines, the index of capital productivity at time ‘t’ can be defined as a ratio of index of output to index of capital input. Symbolically, it can be expressed as:

\[
KP(t) = \frac{Q(t)}{K(t)} \quad (1.2)
\]
Besides, the partial productivity indices of labour and capital inputs, we consider the capital labour ratio, popularly known as capital intensity. This ratio is not only of intrinsic interest as a measure of capital deepening but it also a determinant of labour productivity. This labour productivity at any point of time can be viewed as a product of capital productivity & capital labour ratio:

\[
Q(t) / L(t) = K(t) / L(t) \times Q(t) / K(t) \ldots \ldots \ldots (1.3)
\]

Taking log both side

\[
\log Q(t) / L(t) = \log K(t) / L(t) + \log Q(t) / K(t)
\]

Taking derivative,

\[
\frac{1}{Q/L} \frac{d}{dt}(Q/L) = \frac{1}{Q/K} \frac{d}{dt}(Q/K) + \frac{1}{K/L} \frac{d}{dt}(K/L)
\]

\[\Rightarrow \ \frac{\dot{Q}/L}{Q/L} = \frac{\dot{Q}/K}{Q/K} + \frac{\dot{K}/L}{K/L}\]

i.e., the growth rate of labour productivity is the sum of growth rates of capital-labour ratio and growth rate of capital productivity.

Following Ahmed (1981), we worked out an index of efficiency of labour input as the difference between the actual & desired rates of growth of labour productivity. Symbolically, the efficiency index, denotes by \(E_L\), as:

\[
E_L = (Q/L)^a - (Q/L)^b \ldots \ldots \ldots \ldots (1.5)
\]

Where,

\[
(Q/L)^a = \text{actual growth rate of labour productivity}
\]

\[
(Q/L)^b = (K/L) + (Q/K) \text{ i.e. desire rate of growth of labour productivity.}
\]

If the actual growth of labour productivity equals to the desired rate of labour productivity then \(E_L\) will become zero. This means that labour productivity is growing
at the rate it should. The capital – labour and output - capital ratios are moving in the correct directions and in right proportions. In other words, both factors are being combining in an efficient manner. The value of $E_L$ may be greater or lesser than zero on account of divergence of actual and desired growth rate of labour productivity. The value $E_L > 0$ occurs only if the actual growth rate exceeds desired growth rate and indicates that production is being organised in such an efficient manner that more gains in the labour productivity becomes possible than is permissible by technical relationship of capital – labour and output – capital ratios. The value $E_L < 0$ exists when actual rate of growth is much lower than the desired rate of growth and then indicates the presence of inefficiency in the use of labour input in the production system because the growth which can be attained under given condition is not attained.

To evaluate the impact of industrial liberalization on labour efficiency, the time from 1980-81 to 2003-04 divided in two sub-periods, Sub-period I, represent the Pre-liberalisation phase i.e. 1980-81 to 1991-92 and Sub-period II represent the time span of 1992-93 to 2003-04. Table 9.1 shows the logarithm value of capital, labour & output ratios for the said time-period.

<table>
<thead>
<tr>
<th>Years</th>
<th>Capital Productivity Q/K</th>
<th>ln (Q/K)</th>
<th>Capital Intensity K/L</th>
<th>ln (K/L)</th>
<th>Labour Productivity Q/L</th>
<th>ln(Q/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-81</td>
<td>0.3963</td>
<td>-0.9250</td>
<td>1.8897</td>
<td>0.636</td>
<td>0.7489</td>
<td>-0.289</td>
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<td>1981-82</td>
<td>0.4095</td>
<td>-0.8920</td>
<td>0.8708</td>
<td>-0.138</td>
<td>0.3566</td>
<td>-1.030</td>
</tr>
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<td>1982-82</td>
<td>0.3908</td>
<td>-0.9390</td>
<td>0.9443</td>
<td>-0.573</td>
<td>0.3690</td>
<td>-0.996</td>
</tr>
<tr>
<td>1983-84</td>
<td>0.3050</td>
<td>-1.1870</td>
<td>1.0272</td>
<td>0.026</td>
<td>0.3133</td>
<td>-1.160</td>
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<tr>
<td>1984-85</td>
<td>0.2502</td>
<td>-1.3850</td>
<td>1.0451</td>
<td>0.044</td>
<td>0.2615</td>
<td>-1.340</td>
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<tr>
<td>1985-86</td>
<td>0.2861</td>
<td>-1.2510</td>
<td>1.1041</td>
<td>0.099</td>
<td>0.3159</td>
<td>-1.152</td>
</tr>
<tr>
<td>1986-87</td>
<td>0.2572</td>
<td>-1.3579</td>
<td>1.0599</td>
<td>0.0581</td>
<td>0.2728</td>
<td>-1.299</td>
</tr>
<tr>
<td>1987-88</td>
<td>0.2935</td>
<td>-1.2258</td>
<td>1.0775</td>
<td>0.0746</td>
<td>0.3003</td>
<td>-1.203</td>
</tr>
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<td>1988-89</td>
<td>0.4199</td>
<td>-0.8677</td>
<td>1.0683</td>
<td>0.0660</td>
<td>0.4486</td>
<td>-0.802</td>
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<td>1989-90</td>
<td>0.3266</td>
<td>-1/1188</td>
<td>1.4244</td>
<td>0.3537</td>
<td>0.4652</td>
<td>-0.765</td>
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<td>1990-91</td>
<td>0.2751</td>
<td>-1.2906</td>
<td>2.2401</td>
<td>0.8065</td>
<td>0.6163</td>
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<td>1991-92</td>
<td>0.1998</td>
<td>-1.6104</td>
<td>2.6850</td>
<td>0.9867</td>
<td>0.5364</td>
<td>-0.623</td>
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<td>1992-93</td>
<td>0.2318</td>
<td>-1.4618</td>
<td>2.5437</td>
<td>0.9336</td>
<td>0.5897</td>
<td>-0.528</td>
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<td>1993-94</td>
<td>0.2359</td>
<td>-1.4420</td>
<td>2.9210</td>
<td>1.0719</td>
<td>0.6891</td>
<td>-0.372</td>
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<td>1994-95</td>
<td>0.2339</td>
<td>-1.4528</td>
<td>3.3792</td>
<td>1.2176</td>
<td>0.7904</td>
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<tr>
<td>1995-96</td>
<td>0.2396</td>
<td>-1.4296</td>
<td>3.4247</td>
<td>1.2310</td>
<td>0.7940</td>
<td>0.248</td>
</tr>
<tr>
<td>1996-97</td>
<td>0.3268</td>
<td>-1.1184</td>
<td>3.4821</td>
<td>1.2476</td>
<td>1.1382</td>
<td>0.129</td>
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<td>1997-98</td>
<td>0.4562</td>
<td>-0.7848</td>
<td>2.9396</td>
<td>1.0782</td>
<td>1.3413</td>
<td>0.294</td>
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<td>1998-99</td>
<td>0.2409</td>
<td>-1.4235</td>
<td>4.88725</td>
<td>1.5836</td>
<td>1.1713</td>
<td>0.158</td>
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<td>1999-2000</td>
<td>0.2188</td>
<td>-1.5193</td>
<td>5.0460</td>
<td>1.6186</td>
<td>1.1043</td>
<td>0.099</td>
</tr>
<tr>
<td>2000-01</td>
<td>0.1993</td>
<td>-1.6127</td>
<td>4.9091</td>
<td>1.5991</td>
<td>0.9786</td>
<td>-0.022</td>
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<td>2001-02</td>
<td>0.1914</td>
<td>-1.6533</td>
<td>4.8419</td>
<td>1.5773</td>
<td>0.9267</td>
<td>-0.076</td>
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<td>2002-03</td>
<td>0.2551</td>
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<td>5.4720</td>
<td>1.6996</td>
<td>1.8733</td>
<td>0.628</td>
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<td>2003-04</td>
<td>0.2491</td>
<td>-1.3899</td>
<td>5.8709</td>
<td>1.7700</td>
<td>1.4624</td>
<td>0.380</td>
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</tbody>
</table>
In sub-period 1 i.e. before liberalization,

\((\frac{Q}{L})^{'i} = (-) 0.0073\)
\((\frac{Q}{K})^{'i} = (-) 0.00539\)
\((\frac{K}{L})^{'i} = 0.027\)

So, \((\frac{Q}{L})^i = \) actual growth rate of labour productivity for sub-period 1 = \((-) 0.0073\)

\((\frac{Q}{L})^b = \) desired rate of growth of labour productivity

\[\begin{align*}
&= (\frac{Q}{K}) + (\frac{K}{L}) \\
&= (-) 0.0054 + 0.027 \\
&= 0.0216
\end{align*}\]

Therefore, in the pre-liberalisation era, actual growth rate of labour productivity was less than desired rate of growth, which indicates the presence of inefficiency in the use of labour input.

In Sub-period II i.e. after liberalization,

\((\frac{Q}{L})^{'ii} = 0.076\)
\((\frac{Q}{K})^{'ii} = -0.022\)
\((\frac{K}{L})^{'ii} = 0.071\)

So, \((\frac{Q}{L})^ii = 0.076\)

\[\begin{align*}
(\frac{Q}{L})^b = (-) 0.022 + 0.071 = 0.049 \\
\end{align*}\]

i.e. \((\frac{Q}{L})^i > (\frac{Q}{L})^b\)

That indicates that production being organised in such an efficient manner that more gains in the labour productivity becomes possible than is permissible by the technical relationship of capital - labour & output -capital ratio.

Therefore, it is very much clear that in the post liberalization era, in the modernized & high-tech production process labour is being used in most efficient manner.
Inter-temporal variations in labour & capital productivity based on linear Spline function:

In this section, an attempt made to evaluate the variation in growth rate of labour & capital productivity in the period of before & after liberalization. The effect of industrial liberalization on the growth of labour productivity measurers has been captured by comparing the growth rate of two sub-period 1980 – 81 to 1991 – 92 & 1992 – 93 to 2003 – 04 based on a linear Spline function.

The equation formulated for sub-period-1 following semi-log equation which takes form:

\[
\log \frac{Q/L}{Q/L_0} = \gamma_1 t + \varepsilon_1
\]

where, \(Q/L\) represents labour productivity. ‘t’ represent time for sub-period 1 i.e. pre liberalization period and \(\varepsilon_1\) is the error term.

For Sub-period – II

\[
\log \frac{Q/L}{Q/L_0} = \gamma_2 t + \varepsilon_2,
\]

where \(t\) represents Post liberalisation period.

In order to tackle the discontinuities in the sub-period wise growth rates, the linear Spline function re-parameterised as:

\[
\log \frac{Q/L}{Q/L_0} = \phi + \sigma_1 \omega_{1t} + \sigma_2 \omega_{2t} + \varepsilon
\]

Where,
\[
\omega_{1t} = t
\]
\[
\omega_{2t} = \begin{cases} 
0 & \text{for } t \leq 1991 - 92 \\
\gt 1991 & \text{for } t > 1991
\end{cases}
\]

The growth rate for any sub-period can be derived as \([\exp(\gamma_i) - 1]\) and \(\gamma_i\) s are obtained as

\[
\gamma_1 = \sigma_1 \\
\gamma_2 = \sigma_1 + \sigma_2
\]

That means \(e^{\gamma_1} - 1\) represent the growth rate of labour productivity for 1980 – 81 to 1991 – 92

And \(e^{\gamma_2} - 1\) represent the growth rate for 1992 – 93 to 2003 – 04
Empirical findings:

Table 9.1 reflect the labour productivity growth rate. Here labour productivity has been defined as Gross real value added at constant price per employee. From the linear spline function analysis,

$$\sigma_1 = 0.0365; \quad t = 1.725; \quad R^2 = 0.748 \text{ (sig.)}$$

$$\sigma_2 = 0.069 \quad t = 1.823; \quad R^2 = 0.083$$

So, growth of labour productivity during 1980–81 to 1991–92

$$e^{r_1} - 1 = 1.037 - 1$$

$$= 0.037$$

on the same line, $$\sigma_1 + \sigma_2 = 0.365 + 0.069$$

$$= 0.1055$$

The growth during 1992–93 to 2003–04 =$$e^{r_2} - 1 = 1.1112 - 1$$

$$= 0.1112$$

So it is very clearly reflected that growth rate of labour productivity in the post liberalization period is far higher than that of pre-liberalisation era.

Growth rate of capital productivity:

Capital productivity has been measured as the ratio of gross real value added to gross fixed capital stock at constant prices.

Table 9.1, shows the inter-temporal variations in capital productivity for over 22 years in Indian Steel sector. In sub-period 1 capital productivity growth rate can be formulated as:

$$\log \frac{Q}{K} = \beta_1 + \phi_1 t + \varepsilon_1 \text{ when } t \leq 1991 - 92$$

And growth rate for sub-period 2 can be formulated as:

$$\log \frac{Q}{K} = \beta_2 + \phi_2 t + \varepsilon_2 \text{ when } t > 1991 - 92$$
In order to tackle the discontinuities in the sub-period wise growth rates, the linear Spline function is formulated as follows:

\[
\log \frac{Q}{K} = \psi + \delta_1 \omega_{1t} + \delta_2 \omega_{2t} + \varepsilon
\]

Where, \( \omega_{1t} = t \)

\[
\omega_{2t} = 0 \text{ for } t \leq 1991
\]

\[
= t-1991 \text{ for } t > 1991
\]

Growth rate for sub-period 1 represented by \( e^{\beta_1} - 1 \) & for sub-period 2 as \( e^{\beta_2} - 1 \) when \( \beta_1 = \delta_1 \) and \( \beta_2 = \delta_1 + \delta_2 \). The comparative analysis of growth pattern of capital productivity between pre & post liberalization periods reveals that, from the linear spline function analysis,

\[
\delta_1 = -0.0368, \ t = -2.286 \ (\text{sig. 0.033})
\]

\[
\delta_2 = 0.0417, \ t = 1.449 \ (\text{sig. 0.163})
\]

Therefore, the growth rate of capital productivity for the period 1980 – 81 to 1991 – 92 was \( e^{\beta_1} - 1 = .9638 - 1 = (-) 0.0362 \)

and the growth rate of capital productivity for the period 1992-93 to 2003-04 was \( e^{\beta_2} - 1 = 1.0049 - 1 = 0.0049 \)

**Graph 9.1**

![Graph showing Capital Productivity, Capital Intensity, and Labour Productivity](image-url)
The above analysis suggests that both labour productivity and capital productivity have registered positive growth rate, and displayed better results in the post-liberalisation period compared to the pre-liberalisation period. In the new economic phase there happened massive modernisation in public sector and there emerged a number of private sector with quite a large volume of capital investment. So capital intensity has taken a sharp upward trend. The injection of massive doses of capital coincided with employment of skilled labour and greater provision of training facilities. Besides this, there happened to be relatively higher capital utilisation and time intensive production to cope with the rising demand in the liberalised regime. All these contributed to a higher efficiency of both labour and capital in the post-liberalisation regime compared to the pre-liberalisation regime.

9.13. Analysis of Total Factor Productivity:

Analysis of factor productivity (partial), clearly reflects the improvement trend in both the factor i.e. labour & capital between in the post industrial liberalisation period over the pre-liberalisation over the pre-liberalisation period. Nevertheless, none of the partial productivity analysis reflects the pattern of change in output to the combined use of all inputs together, so the question of total factor productivity arises.

A partial productivity index of course provide a reasonable indication of efficiency in resource use provided the resources not included in the index were of small importance or moved in the same direction as the resource under consideration. However there are severe criticism against such use of partial productivity – one point to note that this partial productivity does not measures the efficiency of labour at all, but the increasing effectiveness with which labour is used in production in conjunction with other inputs.

In the context of the qualms about the reliability of single factor productivity, (partial productivity) emphasis can be given to the measurement of total factor productivity (TFP) as measures of changes in steel production performance.

Again when all factors do not move in same direction and there is substantial factor substitution, partial indices can be seriously misleading. Moreover, the partial
productivity analysis fails to make account of the contribution of a single factor to the growth of the total output. In contrast to this, the total factor productivity provides a rough estimation of efficiency with which all the resources were being used up. Total factor productivity growth is defined as the difference between the rate growth of output and the rate of growth of inputs, appropriately weighted.

This section surveys the index number theory and methods for the measurement of aggregate productivity as characterised by total factor productivity (TFP) and total factor productivity growth (TFPG). An attempt has been made to point out the connection among the major variables, which interact with each other in shaping the prospect of the Indian steel industry, and comparison has been made between pre and post liberalization era. For the purpose of the study, we started with the period 1980–81 up to 2003–04 and divided the entire span in two sub-period for 1980–81 to 1991–92 and 1992–93 to 2003–04. Corresponding data set has been collected from the Annual Survey of Industries.

In most of the empirical studies of TFP, either the Kendrick index or the Solow index has been used. In some of recent studies we observe the use of approximation of Divisia index (in Translog Index).

9.14. Kendrick Index:

Kendrick (1961) argues that the factors used in production can be classified into two factor classes labour and capital and these factors be aggregated in terms of their corresponding monetary cost and application of productivity concept in terms of cost per unit of output or output per unit of cost may bring enough sense. He therefore, suggested a measure of productivity in terms of productivity index,

$$A_t = \frac{Y_t}{w_0 L_t + r_0 K_t}$$
Where, $w_0$ denotes the factor rewards of labour i.e. employees emolument rate in 1980-81.

$\Rightarrow$ Total emolument in 1980 – 81 / Total Employees

$K_0 =$ Value of gross fixed capital in 1980 – 81 / 100

$r_0 =$ factor rewards of capital (accounting sense)

i.e. $(Y_0 - w_0 L_0) / K_0 \Rightarrow (GVA - Emolument) / K_0$

$K_t =$ Physical amount of capital in period t

The index measures average productivity of an arithmetic combination of labour and capital with base year period factor prices. It assumes a linear and a homogeneous production function of degree one. Besides constant returns to scale and neutral technical progress, it assumes an infinite elasticity of substitutability between labour and capital. The index can be generalised to allow for more than two factors.

If a sufficiently long time series for this index can be constructed, then a trend rate of growth can be estimated econometrically. From the time series of Kendrick index yearly series ($g_t$) can be formed by writing growth between successive years as:

$$g^K_{t+1} = (A_{t+1} - A_t) / A_t$$

The growth rates thus obtained can be appropriately averaged for sub-periods.

9.15. Solow Index:

On the other hand Solow Index can be constructed as an index of TFP. This can be done in the following ways:

$$TFP = \frac{\Delta A}{A} = \frac{\Delta Y}{Y} - [S_L \cdot \Delta K / K + S_L \cdot \Delta L / L]$$

Where, $S_L =$ Total emolument of labour / GVA

And, $1 - S_L = S_k$

$A(t)$ may be defined as the growth rate (exponential) in TFP between the year $t-1$ & $t$.

Let $A$ denotes the TFP index.

$$A (1 + 1) = A(t) [1 + \Delta A / A], \text{ by definition } A(0) = 1$$

$$A (1) = A (0) [1 + \Delta A / A]$$

$$A (2) = A(1) [1 + \Delta A / A]$$
Though Solow index based on Cobb-Douglas Production Function tacitly assumes the unitary elasticity of substitution, the non-unitary elasticity of substitution is unlikely to make significant difference to the estimate of TFP. It is also interesting to note here that under the assumption of competitive equilibrium the Solow index and the Kendrick index are almost equivalent for small changes in output and input.

9.16. Translog Index:

The need for using the Divisia Index has been noted by Solow (1957) and Jorgenson & Griliches (1967). Subsequently many analysts have used approximations to Divisia Index (known as Translog index) in their own studies. The computation of TFP by the translog index can be summarised as under:

For two input model (e.g. capital & labour). The translog index of TFP is

$$\frac{\Delta A}{A} = \left[ \log \left( \frac{y_t}{y_{t-1}} \right) - \frac{1}{2}(S_{K_t} + S_{K_{t-1}}) \log \left( \frac{K_t}{K_{t-1}} \right) + \frac{1}{2}(S_{L_t} + S_{L_{t-1}}) \log \left( \frac{L_t}{L_{t-1}} \right) \right]$$

Where, $Y_t$, $L_t$, $K_t$ are respectively value added output, labour input & capital input in year $t$.

$S_L$ & $S_K$ defined as,

$S_L = 1 - S_K$

i.e. $S_L + S_K = 1$

$S_L$ = Total emolument of labour / Gross value added i.e. Share of labour in value added in year $t$.

The production function under laying the Translog index based on two neo-classical assumptions, viz.

(a) Constant returns to scale, and

(b) Payment of factors according to marginal product (that’s why $S_K + S_L = 1$)

This expresses TFP as the difference between growth rate of output and weighted average of growth rates of labour and capital input. This is equivalent to Tornquist’s discrete approximation to continuous Divisia index. The index is based on the translog function which describes the relationship between output and inputs and also between the aggregate and its components. The homogeneous translog functional form is flexible in the sense that it can provide a second order approximation to an
arbitrary twice continuously differentiable linear homogeneous function. This functional form helps overcome the problem which arises with the Solow index where discrete set of data on prices and quantities need to be used in a continuous function. This index also imposes fewer a priori restrictions on the underlying production technology. The index can be generalised for more than two inputs.

Like in the previous case, from year to year changes in productivity growth one can construct a time series of the translog index as follows:

\[ A(t + 1) = A(t) [1 + \Delta A/A], \text{ where } A(0) = 1 \]

Turning back to the formula given above, the first term on right hand side is the growth rate in output (Since log is base e). The second expression as the growth rate of total input (being a weighted average of growth rates of various inputs). So the left hand side gives the growth rate of TFP between \((t - 1)\) and \(t\). Since we are interested, only in the growth rates, then the formula can be applied and the TFP growth rate can be obtained. As our study covers the period 1980 – 81 to 2003 – 04, then TFP growth rate can be computed between 1981 and 82 between 1982 and 1983 and so on. The growth rates computed for different years can be used to compute the average annual rate of TFP growth.

9.17. Empirical Findings:

On the basis of data available in Annual Survey of Indian Industries the analysis of Total Factor Productivity and the index of productivity has been computed. With the help of Spline function analysis growth rate of factor productivity for pre-liberalisation and post-liberalisation is compared here. The findings and comparative study is reflected in this following table. (table no.9.2)
<table>
<thead>
<tr>
<th>YEAR</th>
<th>Rate of Growth of TFP at Constant Price ( dA/A )</th>
<th>TFP (Translog Index at Constant Price ( A_t ))</th>
<th>Rate of Growth of TFP at Constant Price ( A_t )</th>
<th>( \ln A_t )</th>
<th>Growth of TFP at Constant Price ( \Delta A/A )</th>
<th>Solow index ( A_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981-82</td>
<td>0.1067</td>
<td>1</td>
<td>1.4309</td>
<td>0.3583</td>
<td>-0.158</td>
<td>1</td>
</tr>
<tr>
<td>1982-82</td>
<td>-0.0171</td>
<td>0.9829</td>
<td>1.4395</td>
<td>0.3643</td>
<td>-0.018</td>
<td>0.825</td>
</tr>
<tr>
<td>1983-84</td>
<td>-0.2380</td>
<td>0.7748</td>
<td>1.1869</td>
<td>0.1713</td>
<td>-0.514</td>
<td>0.698</td>
</tr>
<tr>
<td>1984-85</td>
<td>-0.2249</td>
<td>0.6187</td>
<td>1.0153</td>
<td>0.0152</td>
<td>-0.187</td>
<td>0.568</td>
</tr>
<tr>
<td>1985-86</td>
<td>0.1169</td>
<td>0.6954</td>
<td>1.2856</td>
<td>0.2512</td>
<td>0.150</td>
<td>0.653</td>
</tr>
<tr>
<td>1986-87</td>
<td>-0.1614</td>
<td>0.5918</td>
<td>1.2033</td>
<td>0.1851</td>
<td>-0.112</td>
<td>0.579</td>
</tr>
<tr>
<td>1987-88</td>
<td>0.0717</td>
<td>0.6358</td>
<td>1.3559</td>
<td>0.3045</td>
<td>0.087</td>
<td>0.629</td>
</tr>
<tr>
<td>1988-89</td>
<td>0.3550</td>
<td>0.9067</td>
<td>2.2482</td>
<td>0.8101</td>
<td>0.492</td>
<td>0.939</td>
</tr>
<tr>
<td>1989-90</td>
<td>-0.1904</td>
<td>0.7495</td>
<td>1.9049</td>
<td>0.6444</td>
<td>-0.131</td>
<td>0.815</td>
</tr>
<tr>
<td>1990-91</td>
<td>-0.0314</td>
<td>0.7263</td>
<td>1.8137</td>
<td>0.5953</td>
<td>-0.103</td>
<td>0.731</td>
</tr>
<tr>
<td>1991-92</td>
<td>-0.2092</td>
<td>0.5892</td>
<td>1.4206</td>
<td>0.3511</td>
<td>-0.246</td>
<td>0.910</td>
</tr>
<tr>
<td>1992-93</td>
<td>0.0322</td>
<td>0.6085</td>
<td>1.8622</td>
<td>0.6218</td>
<td>0.178</td>
<td>1.072</td>
</tr>
<tr>
<td>1993-94</td>
<td>0.0520</td>
<td>0.6409</td>
<td>1.9975</td>
<td>0.6919</td>
<td>0.069</td>
<td>1.146</td>
</tr>
<tr>
<td>1994-95</td>
<td>0.00018</td>
<td>0.6411</td>
<td>2.2084</td>
<td>0.7923</td>
<td>0.010</td>
<td>1.158</td>
</tr>
<tr>
<td>1995-96</td>
<td>0.0185</td>
<td>0.6431</td>
<td>2.3270</td>
<td>0.8446</td>
<td>0.055</td>
<td>1.222</td>
</tr>
<tr>
<td>1996-97</td>
<td>0.2819</td>
<td>0.8637</td>
<td>3.1713</td>
<td>1.1541</td>
<td>0.325</td>
<td>1.619</td>
</tr>
<tr>
<td>1997-98</td>
<td>0.3008</td>
<td>1.1695</td>
<td>4.5569</td>
<td>1.5166</td>
<td>0.135</td>
<td>1.838</td>
</tr>
<tr>
<td>1998-99</td>
<td>-0.5462</td>
<td>0.6773</td>
<td>2.5398</td>
<td>0.9321</td>
<td>-0.606</td>
<td>2.953</td>
</tr>
<tr>
<td>1999-00</td>
<td>0.0900</td>
<td>0.6190</td>
<td>2.1332</td>
<td>0.7576</td>
<td>-0.082</td>
<td>2.708</td>
</tr>
<tr>
<td>2000-01</td>
<td>-0.1679</td>
<td>0.5233</td>
<td>2.0930</td>
<td>0.7386</td>
<td>-0.085</td>
<td>2.476</td>
</tr>
<tr>
<td>2001-02</td>
<td>-0.065</td>
<td>0.4904</td>
<td>2.0343</td>
<td>0.7101</td>
<td>-0.099</td>
<td>2.228</td>
</tr>
<tr>
<td>2002-03</td>
<td>0.3269</td>
<td>0.6800</td>
<td>2.7527</td>
<td>1.0126</td>
<td>0.398</td>
<td>3.115</td>
</tr>
<tr>
<td>2003-04</td>
<td>0.0343</td>
<td>0.7037</td>
<td>2.8163</td>
<td>1.0354</td>
<td>-0.011</td>
<td>3.081</td>
</tr>
</tbody>
</table>
Table: 9.3  **Result of the analysis**

<table>
<thead>
<tr>
<th></th>
<th>Solow</th>
<th>Kendrick</th>
<th>Translog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of $R^2$</td>
<td>0.896</td>
<td>0.648</td>
<td>0.118</td>
</tr>
<tr>
<td>Value of $F$</td>
<td>90.12 (sig. 0.000)</td>
<td>19.32 (sig. 0.000)</td>
<td>2.819 (sig. 0.0108)</td>
</tr>
<tr>
<td>$\delta^1$</td>
<td>0.01</td>
<td>0.055</td>
<td>-0.0251</td>
</tr>
<tr>
<td></td>
<td>($t = 0.793$)</td>
<td>($t = 3.416$)</td>
<td>($t = -1.741$)</td>
</tr>
<tr>
<td></td>
<td>(sig. 0.437)</td>
<td>(sig. 0.003)</td>
<td>(sig. 0.116)</td>
</tr>
<tr>
<td>$\delta^2$</td>
<td>0.113</td>
<td>0.0249</td>
<td>0.396</td>
</tr>
<tr>
<td></td>
<td>($t = 4.989$)</td>
<td>($t = 0.879$)</td>
<td>($t = 0.339$)</td>
</tr>
<tr>
<td></td>
<td>(sig. 0.000)</td>
<td>(sig. 0.389)</td>
<td>(sig. 0.742)</td>
</tr>
<tr>
<td>Growth rate in pre-liberalisation regime $= e^{\delta^1}$</td>
<td>0.01</td>
<td>0.056</td>
<td>-0.0247</td>
</tr>
<tr>
<td></td>
<td>($t = 0.793$)</td>
<td>($t = 3.416$)</td>
<td>($t = -1.741$)</td>
</tr>
<tr>
<td></td>
<td>(sig. 0.437)</td>
<td>(sig. 0.003)</td>
<td>(sig. 0.116)</td>
</tr>
<tr>
<td>Growth rate in post-liberalisation regime $= e^{\delta^1 + \delta^2}$</td>
<td>0.13</td>
<td>0.083</td>
<td>0.0146</td>
</tr>
</tbody>
</table>

**Observation:**

From the above table it is observed that in terms of the Spline function analysis, TFP in terms of Kendrick index, Translog index and Solow index has registered greater growth rate in the post-liberalisation regime compared to the pre-liberalisation regime. This result is in consonance with the behaviour of partial productivity series in the respective period. In the post-liberalisation phase, entry of the green field units with state of arts technology, massive modernisation programme of the primary producers, higher capital and resource utilisation improves labour skill, efficient monitoring in the part of management as well as government are suppose to be responsible for the increased productivity scenario.
9.18. Parametric Approach

Parametric approach consists in econometric estimation of production functions to infer contributions of different factors and of an autonomous increase in production over time, independent of inputs. This latter increase, which is a shift over time in the production function, can be more properly identified as technological progress. It is one of the factors underlying productivity growth. An alternative to estimation of production functions is estimation of cost functions using results from the duality theory. Below we give some commonly used specifications of production functions.

9.19. Transcendental Logarithmic (TL) Specification:

The Transcendental Logarithmic (or so called Translog) Production Function has been developed by Christensen, Jorgenson & Lau (1973). The Translog Production Function Specification is a flexible functional form imposing relatively few a priori restrictions on the properties of the underlying technology. It allows for variable elasticity of substitution, variable scale elasticity and non-neutral technological progress. Homotheticity, separability and constant returns to scale can be imposed by testable restriction on the parameters, and the form reduces to the multiple input Cobb-Douglas specification as a special case. The Translog production function and general factor augmenting technical progress takes the form:

\[
\log Q = \alpha_0 + \alpha_1 t + \beta_{11} t^2 + \alpha_L \log L + \alpha_K \log K + \beta_{KL} \log K \log L + \frac{1}{2} \beta_{KK} (\log K)^2 + \frac{1}{2} \beta_{LL} (\log L)^2 + \beta_{Kt} (\log K) t + \beta_{Lt} (\log L) t
\]

Where, \(\alpha\)'s and \(\beta\)'s are the parameters of the production function.

The rate of technical progress or total factor productivity growth is given by

\[
\frac{\partial \log Q}{\partial t} = \alpha_1 + 2\beta_{11} t + \beta_{Kt} (\log K) + \beta_{Lt} (\log L)
\]

Where,

\(\alpha_1\) is the rate of autonomous total factor productivity growth.

\(\beta_{11}\) is the rate of change of TFPG, and

\(\beta_{Lt}, \beta_{Kt}\) define the bias in TFPG.
If both $\beta_{Lt}$ and $\beta_{Kt}$ are zero, then the TFPG is Hicks-neutral type. If $\beta_{Lt}$ is positive then the share of labour increases with time and there is labour using bias. Similarly, a positive $\beta_{Kt}$ will show a capital using bias.

Table: 9.4. Result of the analysis:

<table>
<thead>
<tr>
<th>Co-efficient</th>
<th>Values</th>
<th>t</th>
<th>Significant level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_t$</td>
<td>-0.104</td>
<td>-2.108</td>
<td>0.54</td>
</tr>
<tr>
<td>$\beta_{tt}$</td>
<td>-0.00045</td>
<td>-1.30</td>
<td>0.212</td>
</tr>
<tr>
<td>$A_L$</td>
<td>3.495</td>
<td>2.18</td>
<td>0.046</td>
</tr>
<tr>
<td>$A_K$</td>
<td>2.398</td>
<td>2.27</td>
<td>0.039</td>
</tr>
<tr>
<td>$\beta_{KL}$</td>
<td>-0.188</td>
<td>-2.12</td>
<td>0.052</td>
</tr>
<tr>
<td>$\beta_{Kt}$</td>
<td>0.00609</td>
<td>2.10</td>
<td>0.054</td>
</tr>
<tr>
<td>$\beta_{Lt}$</td>
<td>0.00443</td>
<td>1.75</td>
<td>0.102</td>
</tr>
<tr>
<td>$1/2\beta_{KK}$</td>
<td>0.004096</td>
<td>0.422</td>
<td>0.679</td>
</tr>
<tr>
<td>$1/2\beta_{LL}$</td>
<td>0.002234</td>
<td>0.733</td>
<td>0.477</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.886</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj $R^2$</td>
<td>0.813</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>12.084</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

9.20. Observation:

From the above table it is found that the productivity function is good fit as the value of $R^2$ is quite high (0.886) and is significant. The values of $\beta_{Kt}$ and $\beta_{Lt}$ are both positive, indicating possible bias in the use of corresponding factors. However at a second glance it is observed that the value of t ratio (1.75) corresponding to the factor labour, though positive but relatively insignificant while that of capital is significant at 5 % level. This indicates a strong argument in favour of capital using bias in production of steel for the entire time period, while that for labour is not validated. The possible reason is the massive modernisation and use of state of arts technology, on the other hand continuous reduction of employment through VRS, others schemes and hire and fire policy.
9.21. Output Elasticity:

In Transcendental Logarithmic Production Function specification, the elasticity of output with respect to labour and capital are not constant as in Cobb-Douglas production function. But depends on the input levels & time. The elasticity of output of each variable is:

$$\frac{\partial \log Q}{\partial \log X_i} = \alpha_i + \sum \beta_{ij} \log X_j + \beta_{jt} t$$

Since elasticity of output as well as factor share varies with input level in the Tanslog production function, the elasticity of substitution is also a function of input level and is not a constant.

Table: 9.5. Empirical findings:

<table>
<thead>
<tr>
<th>Year</th>
<th>Elasticity of output w.r.t. capital</th>
<th>Elasticity of output w.r.t. labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-81</td>
<td>-0.052</td>
<td>0.961</td>
</tr>
<tr>
<td>1981-82</td>
<td>-0.203</td>
<td>0.953</td>
</tr>
<tr>
<td>1982-82</td>
<td>-0.20</td>
<td>0.936</td>
</tr>
<tr>
<td>1983-84</td>
<td>-0.191</td>
<td>0.928</td>
</tr>
<tr>
<td>1984-85</td>
<td>-0.196</td>
<td>0.915</td>
</tr>
<tr>
<td>1985-86</td>
<td>-0.161</td>
<td>0.939</td>
</tr>
<tr>
<td>1986-87</td>
<td>-0.155</td>
<td>0.946</td>
</tr>
<tr>
<td>1987-88</td>
<td>-0.142</td>
<td>0.956</td>
</tr>
<tr>
<td>1988-89</td>
<td>-0.127</td>
<td>0.969</td>
</tr>
<tr>
<td>1989-90</td>
<td>-0.061</td>
<td>0.977</td>
</tr>
<tr>
<td>1990-91</td>
<td>-0.069</td>
<td>0.881</td>
</tr>
<tr>
<td>1991-92</td>
<td>-0.032</td>
<td>0.880</td>
</tr>
<tr>
<td>1992-93</td>
<td>-0.051</td>
<td>0.909</td>
</tr>
<tr>
<td>1993-94</td>
<td>-0.031</td>
<td>0.859</td>
</tr>
<tr>
<td>1994-95</td>
<td>-0.014</td>
<td>0.846</td>
</tr>
<tr>
<td>1995-96</td>
<td>-0.022</td>
<td>0.832</td>
</tr>
<tr>
<td>1996-97</td>
<td>0.016</td>
<td>0.863</td>
</tr>
<tr>
<td>1997-98</td>
<td>0.021</td>
<td>0.897</td>
</tr>
<tr>
<td>1998-99</td>
<td>0.041</td>
<td>0.818</td>
</tr>
<tr>
<td>1999-2000</td>
<td>0.523</td>
<td>0.819</td>
</tr>
<tr>
<td>2000-01</td>
<td>0.086</td>
<td>0.856</td>
</tr>
<tr>
<td>2001-02</td>
<td>0.105</td>
<td>0.874</td>
</tr>
<tr>
<td>2002-03</td>
<td>0.122</td>
<td>0.865</td>
</tr>
<tr>
<td>2003-04</td>
<td>0.130</td>
<td>0.857</td>
</tr>
</tbody>
</table>

138
9.22. Observation:

The above result reveals that, the elasticity of output w.r.t capital has gradually increased over time, turning to be positive from negative from 1996-97 onwards. On the contrary the Elasticity of output w.r.t. labour, all though, in absolute value higher than that of capital, is gradually decreasing overtime. This is indicative of the fact that, the relative importance of capital in influencing output has gradually increased overtime compared to that of labour. The negative expression of elasticity of capital can be interpreted in terms of under utilisation of capital and relative in efficient use of labour in relation to of injected capital. This phase gradually came to be removed from 1996. This indirectly hints at the relatively increased responsiveness of output to capital compared to labour in the liberalised regime. In other words, introduction of sophisticated techniques and quality machinery has enhanced the relative dependence of output of steel to capital in comparison to labour input.

9.23. Validity of Verdoorn law for Indian Steel Sector:

Verdoorn Law is based on the empirical results of the study by Verdoorn (1949), who concluded that over a long period there is a fairly constant relationship between growth in output and growth in labour productivity: Verdoorn Law specifies that on the average, the elasticity of labour productivity with respect to output is 0.45, the broad range of values lies between 0.41 to 0.57. However, many studies reported that the Verdoorn coefficient (i.e. elasticity of labour productivity with respect to output) lies between the range 0.4 and 0.7 [ Aggarwal aqnd Kumar(1991) and Ghosh (1996)].

There are two important specifications of Verdoorn Law: (1) Kaldor’s specification (signifying the impact of annual growth rate of output on annual growth rate of labour productivity); and Rowthorn’s specification (signifying the impact of annual growth rate of labour employment on annual growth of labour productivity). Kaldor specifies the aggregate Verdoorn law as a regression equation as –
\[ \dot{LP} = f(Q) \]
\[ LP = \alpha_1 + \beta_1 \dot{Q} \]

Where \( \dot{LP} \) and \( \dot{Q} \) are the growth rate of labour productivity and output.

But Rowthom’s specifies the aggregate Verdoorn’s Law as:

\[ \dot{LP} = f(\dot{L}) \]
\[ LP = \alpha_2 + \beta_2 \dot{L} \]

Where \( \dot{LP} \) and \( \dot{L} \) are the growth rate of labour productivity and employment.

Regression Estimation of Verdoorn law for Indian Steel Sector (empirical findings):
Table 9.6: Result obtained:

**Kaldor Specification**

<table>
<thead>
<tr>
<th>Pre liberalisation regime</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( R^2 )</td>
<td>0.367</td>
<td>5.22</td>
<td>0.297</td>
<td>0.682</td>
</tr>
<tr>
<td>( F )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Adj. R^2 )</td>
<td>0.297</td>
<td>0.297</td>
<td>2.285</td>
<td>0.048</td>
</tr>
<tr>
<td>( \beta_1 )</td>
<td>0.682</td>
<td>0.682</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Sign level )</td>
<td>0.048</td>
<td>0.048</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Post Liberalisation regime:

|   |   |   |   |   |
|---|---|---|---|
| \( R^2 \)               | 0.629 | 16.938 | 0.592 | 1.318 |
| \( F \)                  |   |   |   |   |
| \( Adj. R^2 \)           | 0.592 | 0.592 | 4.116 | 0.002 |
| \( \beta_1 \)            | 1.318 | 1.318 |   |   |
| \( t \)                  |   |   |   |   |
| \( Sign level \)         | 0.002 | 0.002 |   |   |

**Rowthorn Specification**

<table>
<thead>
<tr>
<th>Pre liberalisation regime</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( R^2 )</td>
<td>0.382</td>
<td>5.57</td>
<td>0.314</td>
<td>-0.387</td>
</tr>
<tr>
<td>( F )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Adj. R^2 )</td>
<td>0.314</td>
<td>0.314</td>
<td>-0.2.36</td>
<td>0.043</td>
</tr>
<tr>
<td>( \beta_1 )</td>
<td>-0.387</td>
<td>-0.387</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Sign level )</td>
<td>0.043</td>
<td>0.043</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Post Liberalisation regime:

|   |   |   |   |   |
|---|---|---|---|
| \( R^2 \)               | 0.637 | 0.384 | 0.059 | -0.229 |
| \( F \)                  |   |   |   |   |
| \( Adj. R^2 \)           | 0.059 | 0.059 | -0.62 | 0.549 |
| \( \beta_1 \)            | -0.229 | -0.229 |   |   |
| \( t \)                  |   |   |   |   |
| \( Sign level \)         | 0.549 | 0.549 |   |   |
Here Verdoorn's law according to Kaldor specification as well as Rowthorn specifications have been analyses for the periods – Pre liberalisation and Post Liberalisation for Indian Steel industry.

It is observer that according to Kaldor specification the impact of output growth on the growth of labour productivity is much higher in Post Liberalisation regime (1.318) compared to pre liberalisation regime (0.682). Both the rates are significant at respectively 0.002 and 0.048 level.

The implication is that in the liberalised regime the labour productivity impact of output has far been sharper than in the post liberalised regime. The efficiency of labour has been increased due to the drive brought in the output factor.

According to Rowthorn specification, the impact of growth of labour employment on labour productivity has been negative. But the magnitude is a higher in the pre liberalisation regime than in the Post Liberalisation regime implying that in the later period, labour productivity has not been affected that sharply as in the former period.