CHAPTER V :

TECHNICAL PROGRESS IN ELECTRICITY IN INDIA

1. CONCEPT OF TECHNICAL PROGRESS

The post war years, for the developed countries, were the years of almost full employment of factors of production. As a result of this phenomenon the economists, in the advanced countries, started paying more attention to the analysis of productivity of factors of production. The productivity of a factor of production is nothing else but the ratio of output to input. Thus, it has been rightly observed by Salter, that, "Unless there is a revolution in statistical techniques and information, only one type of productivity concept is measurable. This is the concept of output per unit of input".[1] There can be as many productivity indices as the number of inputs that one can manage to classify and measure. Further, "Productivity change is both the cause and the consequence

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1 W.E.G. Salter : Productivity and Technical Change, Cambridge University Press, 1966 (2nd ed.), p.2.

of the evolution of dynamic forces operating in an economy - technical progress, accumulation of human and physical capital, enterprise and institutional arrangements."[2]

Thus, technical progress is one of the important factors affecting the growth of an industry or an economy. Following Kennedy and Thirlwall, we may observe that the term technical progress may be used to refer to, "First, the effects of changes in technology, or more specifically the role of technical progress in the growth process. Secondly,... changes in technology itself, defining technology as useful knowledge pertaining to the art of production."[3] Technical progress is further defined by Solow as "a shorthand expression for any kind of shift in the production function."[4] Technical progress itself requires three types of inputs: "first, research type inputs, secondly, knowledge distribution inputs (e.g. education), and thirdly, inputs required for changing over to improved industrial methods."[5]

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2 Nadiri Ishaw M., "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey" in The Journal of Economic Literature, December, 1970, p.1137.

3 Charles Kennedy & A.P.Thirlwall: "Technical Progress" in Survey of Applied Economics, Vol.I, p.116.

4 R.M.Solow, "Technical Change and Aggregate Production Function", in Review of Economics and Statistics, Vol.39, 1957, p.312.

5 Kennedy & Thirlwall, op.cit., p.117.

The problem that one faces while observing the technical progress is the difficulty of quantifying the advances in technical knowledge. Thus, to analyse the technical progress we observe its effects on the growth of national income or that of factor productivity. Thus, the impact of technical progress is observed by treating it as a residual that remains after making an allowance for the contribution of other inputs in the growth of output. This method of measuring technical progress suffers from a serious disadvantage due to its inability to separate the effects of technical progress from the effects of unspecified inputs.

There are two main causes which lead to a change in the technique of production. Quoting from Salter again, we have, "In a growing economy two main forces shape the flow of new techniques which we observe coming into use: improving technical knowledge expands the realm of the technically feasible, and changing factor prices alter the terms of choice between technical alternatives."[6] The technical progress is characterised by two important features viz., continuous disturbance on account of new technique coming up even before the old technique has completely worked itself; out; and the slow

6 ~~Ibid~~, p.13.
Op.Cit.

adjustment to the new techniques.Salter, further, observes the three effects of technical change. These effects are: "(1) the general effect of the rate of technical advance, (2) the bias effect arising out of technical change which tends to save more of one factor than another, and (3) the substitution effect reflecting changes in relative factor prices, including those arising out of technical progress in the manufacturing of capital goods."[7]

The most popular method of measuring technical progress is to estimate the geometric index of factor productivity which is derived from the multiplicative form of production function. Thus, technical progress is measured by analysing the total productivity of factors of production. The most widely used form of production function is the Cobb-Douglas production function. Before estimating the total factor productivity, one has to decide whether any adjustment for the quality of the input is to be made or not. This decision depends on the objective of the study. If the intention behind the study is to observe changes in the factor productivity then one need not make adjustments for the quality changes in the factor. If on the other hand, the objective

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7 Ibid, p.45.

is to analyse the advances in knowledge, then one has to make some adjustment for the changes in the quality of the input.

Having taken the decision about the adjustments to be made, or not, for the quality of an input, we try to measure the contribution of technical progress in the growth of an economy. As already mentioned above, in order to estimate the technical progress usually we fit a Cobb-Douglas production function to the data. The Cobb-Douglas production function is based on the assumptions of neutral technical progress, unitary elasticity of substitution between factors of production and constant returns to scale. The Solow model makes a further assumption of disembodied technical progress. Due to these assumptions the model may not measure technical progress at all. What is classified as technical progress may be the result of substitution effect between labour and capital, economies of scale, organisational advances, education and many such factors including errors of measurement. These are some of the problems associated with the measurement of technical progress. One has to keep in mind these limitations of the Cobb-Douglas production function while interpreting the results of the model.

2. ESTIMATES OF TECHNICAL PROGRESS

For measuring the technical progress, we have applied two models to the available data. The data of capital input are the adjusted data, as already discussed in the chapter on Capital Productivity. The rate at which output of an industry grows is ultimately dependent on the rate of growth of capital input, labour input and on technical progress. The growth in output can be attributed to the growth in capital and labour and whatever is not explained by capital and labour is termed as technical progress. Thus, technical progress is a residual that embodies all the other factors not included in labour and capital. Technical progress, in other words, shows the shift in the production function. To put the relationship, between output, capital input, labour input and technical progress; in the form of notations we have :

$$g = \lambda + \alpha \div \quad l + \beta . k$$

where g, l and k represent annual rates of growth in output, (G), labour input (L) and capital input (K). α and β denote the production elasticities of labour and capital respectively. λ indicates the annual rate of shift in the production function. In this function g, l and k are directly estimated from the output, labour and capital series. The g, l and k are estimated by regressing G, L and K over time in semi-log form; $G_t = G_o e^{gt}$, $L_t = L_o e^{lt}$, $K_t = K_o e^{kt}$, λ , α and β are to be estimated by specifying the production function that incorporates trend variable, (t) explicitly. Thus we have the relation $G=f(L,K,t)$. The values of λ, α and β are estimated by applying two different models to the available data. Output G is defined as gross value added at constant prices. Capital input, K, is the adjusted capital series at constant prices. Labour input L is the average daily employment in electricity generation, transmission and distribution. We take the period 1956-57 to 1970-71 because for the earlier years data relating to labour input are not available as seen in Chapter III.

Looking at the rates of growth of G, K and L, given in the table below; we notice that the labour input has a higher rate of growth as compared to capital.

	1956-57 to 1970-71
g	0.14318
l	0.10842
k	0.10537

It can be easily seen from the above written table that output (G) increased at an average annual rate of 14.32 %, labour at 10.84% and capital at 10.54%. The productivity of labour, defined as (g-l), shows an annual increase of 3.48 per cent. Similarly, the capital productivity, defined as (g-k), shows an annual increase of 3.78%. Thus, we can say that the capital productivity exhibited a slightly higher annual increase than labour productivity.

Model I :

First of all we apply the first model to the data for electricity industry over a period of 14 years.

Assuming constant returns to scale, we have the famous Cobb-Douglas production function of the form :

$$\frac{G}{L} = Ae^{\lambda t} \left(\frac{K}{L} \right)^{\beta} \qquad ...(1)$$

The above written relation can be expressed as :

$$\log \left(\frac{G}{L} \right) = \log A(t) + \beta \log \left(\frac{K}{L} \right)$$

This relation can be further expressed in its incremental form by taking the difference between two neighbouring terms. In other words it can be written as :

$$\Delta \log \left(\frac{G}{L} \right) = \Delta \log A(t) + \beta \Delta \log \left(\frac{K}{L} \right)$$

This can be approximately written as

$$\frac{\Delta (G/L)}{(G/L)} = \frac{\Delta A(t)}{A(t)} + \beta \frac{\Delta (K/L)}{(K/L)}$$

Thus, we have the value of $\frac{\Delta A(t)}{A(t)}$ to be :

$$\frac{\Delta A(t)}{A(t)} = \frac{\Delta (G/L)}{(G/L)} - \beta \frac{\Delta (K/L)}{(K/L)} \qquad \ldots.(2)$$

This relation (2) forms our Model I. In this model the A(t) series gives us the shift in the production function. The A(t) series is estimated from the series of Δ A(t) by taking the initial value of A(t) to be equal to one. From this series the value of λ is estimated by the following formula :

$$\lambda = \frac{A_t - A_1}{n}$$

Where A_t is the value of A(t) for the terminal year and A_1 is the value of A(t) for the initial year. n stands for the number of observations.

By applying the first model to the available data on output (i.e. gross value added at 1970-71 prices), Labour input and capital input (i.e. adjusted capital series at 1970-71 prices) we get the A(t) series, as discussed above. β is the observed share of profit defined as the ratio of balance carried over to gross value added at current prices.

Observing the A(t) series in Table V.1, we notice that the value has gone up from 1.00000 to 1.61788, giving us an 61.79 per cent increase in the A(t) value over a period of 14 years. This gives us the value of λ to be .041192. λ represents the annual rate of shift in the production function. This model gives us the trend coefficient to be 4.12 per cent, which is substantially higher than the trend coefficient as estimated by S.R.Hashim and M.M. Dadi, for the manufacturing sector from 1946 to 1964. (Their trend coefficient for the Model I being 2.82 per cent)*. These results, of course, are not strictly comparable because the time period is not the same for both the studies and the sources of data are also different. But, all the same, as an indicator of the divergent situations the comparison can be permitted. Electricity, as compared to manufacturing

8 Hashim S.R. and Dadi M.M.: op.cit., p.78.

* The compound rate of shift comes to be 3.49%.

Table V.1

Shift in Production Function

Year	$\frac{\Delta(G/L)}{(G/L)}$	β	$\frac{\Delta(K/L)}{K/L}$	A(t)
1	2	3	4	5
1956-57	-	-	-	1.00000
1957-58	0.08371	0.37654	-0.09552	1.11968
1958-59	0.02995	0.35481	0.05801	1.12904
1959-60	-0.03873	0.38532	-0.12569	1.13874
1960-61	-0.07582	0.41211	-0.11014	1.10831
1961-62	-0.10010	0.43974	-0.18977	1.09166
1962-63	0.03558	0.41044	0.05961	1.10277
1963-64	0.21878	0.39802	0.06751	1.29467
1964-65	0.12998	0.41536	-0.02816	1.43635
1965-66	-0.05639	0.37927	0.08422	1.34802
1966-67	0.06264	0.38109	0.10605	1.37025
1967-68	0.06818	0.35470	0.03246	1.42691
1968-69	0.11357	0.36314	0.07697	1.51253
1969-70	-0.01028	0.36750	0.00643	1.49989
1970-71	0.11475	0.43963	-0.00738	1.61788

Notes:

1. G is the gross value added at 1970-71 prices.
2. K is the adjusted capital series at 1970-71 prices. See Chapter IV.
3. β is the observed profit share.
4. L is the labour input.
5. A(t) is series that gives the annual rate of shift in the production function.

sector, is more capital intensive and being a public utility more sensitive to demand pressures. At the same time this high value of trend coefficient may be the result of a high degree of underutilization of installed capacity in the earlier years. With the passage of time capacity utilisation in electricity has improved in the sense that the plant factor has improved i.e. the ratio of maximum demand to installed capacity has significantly improved from 63.7% in 1951-52 to 85.2% in 1970-71.[9] This must have been absorbed by the technical progress. Therefore, one has to accept the fact that the value of the trend coefficient may be an inflated value.

Model II :

Releasing the assumption of constant returns to scale we get the modified version of the Cobb-Douglas Production Functions. Thus, in the functional form, we have the model II written as :

$$G = Ae^{\lambda t} L^{\alpha} K^{\beta};$$

where G stands for gross value added, at 1970-71 prices; L is the labour input and K is the adjusted capital series, at

9 Public Electricity Supply, op.cit.

1970-71 prices. In this model λ gives us the rate of technical progress, α and β are the production elasticities with respect to labour and capital, respectively. Observing the results given in Table V.2, we notice a very high rate of technical progress; the value of λ being 0.08694 and a very low value of β viz., 0.03825. Further, observing the t value of the parameters estimated we note that neither λ nor β is significant even at 5% level of significance. It is only the value of α that is significant at 5% level of significance.

Table V.2

The Values of , and , R^2 and their t values

Time period	λ	α	β
1956-57 to 1970-71	0.08694	0.47787	0.03825
t value	1.3253	2.8244*	0.0710

* Significant at 5 per cent level of significance.

From the results given above it appears that the value of λ is an overestimation and that β an underestimation. The capacity utilisation in electricity industry over a period of time has gone up. (Defining capacity utilisation as plant factor). This better utilisation of existing plants must have been captured in the value of technical progress, giving us an inflated figure for λ and an underestimation for β . Over a period of time bigger generating plants have been substituting smaller and uneconomic plants in generation of electricity resulting in the economies of scale. These economies also must have been captured in the technical progress. We observe a similar tendency for technical progress to capture all the unspecified factors in the growth of an industry; when we try to segregate the contribution of technical progress, labour input and capital input in the growth of output. The information given below, in Table V.3 brings out the contribution of all the three factors in the growth of output of electricity.

Table V.3

Components of Growth in Electricity Utility in India

Time period	λ	αl	βk	g*
1	2	3	4	5
1956-57 to 1970-71	0.08694	0.05181	0.00403	0.14278
Percentage share	60.89	36.29	2.82	100.00

* g is the summation of columns 2, 3 and 4.

From the figures given above we see that technical progress contributes about 61% of growth in output of electricity. As against this the contribution of capital is extremely low, viz., 2.82%. Comparing our results with those of Hashim and Dadi[10] we see that the contribution of technical progress, in Indian Manufacturing was about 50%; in the growth of output of these industries.

While comparing the two results one has to bear in mind the fact that not only the sources of data are different but the time covered by their study (1946-1964) is different from our study. All the same, we expect a higher value for technical progress in electricity as compared to manufacturing sector as a whole, because it has tremendous economies of scale; which are likely to be captured by technical progress.

In concluding this chapter we may say that, inspite of the possible overestimation of technical progress, technical progress does seem to be an important factor responsible for the growth of electricity industry.

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10 Op.cit., p.80.