UNIT 5 TOTAL FACTOR PRODUCTIVITY AND GROWTH ACCOUNTING

Structure

5.0 OBJECTIVES

After reading this unit, you will be able to:

- Explain the cbncept of total factor productivity;
- State the factors that affect productivity;
- Elucidate the relationship of productivity and growth accounting;
- Describe the methods to measure productivity; and
- Discuss the issues and debates related to productivity analysis.

5.1 INTRODUCTION

Total Factor Productivity (TFP) or we may call it productivity is an important concept in the context of economic Growth of a nation particularly developing countries. Productivity contributes to industrial growth and to the competitiveness in international markets. It refers to the rate at which employment is generated from the employed resources. Increased productivity result in better utilisation of resources and reduces the cost and the prices of industrial products, which in turn, lead to a faster growth in demand in both domestic and international markets.

The origin of the term can be traced to the "Abramovitz residual," which refers to the growth of output unaccounted for by the factor inputs (Abrarnovitz, 1956). However ever since Solow (1357) decomposed output growth into the contribution of input growth and a residual productivity term; the concept has gained popularity and is used as a benchmark. to rank firms or countries. Such rankings get credibility once

productivity is correlated with other indicators of success such as employment growth, export status, or technology adoption. Concept like low productivity is also found useful to predict exit of the firms in an economy, the ultimate performance standard. Its importance can also be gauged from the attention it receives as a criterion to evaluate policy interventions or firms' decisions. The concept has relevance and different meaning in different branches of economics. In industrial economics, for example, a large literature investigates the effect of R&D on productivity and the resulting impact on industry structure. In international economics, the efforts to evaluate the iinpact of trade liberalization range from estimating changes in price-cost margins to productivity changes. Fundamentally, the objective of productivity measurement is to identify changes in output that cannot be explained by changes in inputs.

Total Factor Productivity (TFP) as a concept is also important not only in the context of macro-economic aggregate measures of a countiy's performance in terms of per capita growth and productivity, but is of equal significance in measuring the determinants of productivity and competitiveness of firms. The hitherto more popular measure – labour productivity or value added per unit labour – suffers from the shortcoming that it does not reveal why the productivity has risen or vicc-versa. Is it due to increased inputs of capital, or are there other causes? The TFP approach while analysing performance, attempts to go into the WHY of productivity changes and thus gives deeper insights into the underlying causes and sustainability of growth.

Productivity keeps on changing as production continues. It improves under favourable circumstances and deteriorates when unfavourable changes occur. The changes that lead to higher productivity of inputs are technological improvements, iinproveinent in efficiency, increased education of labour, improvement in the quality of labour due to training, etc. Today, TFP is considered an important source of output growth worldwide due to rapid progress in science and technology and various efficiency-enhancing measures.

5.2 TOTAL FACTOR PRODUCTIVITY: DEFINITION

Total factor productivity as a concept has been formalised in the second quarter of the last century. Although the origin of the idea on its existence might be sought as early as the classical school, more serious attempts to find a stricter definition are observed after the 1930s. Behind this concept most often stands the understanding that besides the traditional factors of production labour and capital there is something else that leads to the increase in production. Usually this 'thing' is associated with technological progress. The latter concept itself can be interpreted invarious ways, but eventually it always implies that the combination of labour force, machines, human knowledge and skills, leads to changes in total income that arc not expected by changes in capital or labour considered separately.

Growth (increase in GDP) of an economy is generally attributed to factors that can be clubbed under two broad headings: Capital and Labour. But you will find when you calculate it that Capital and Labour cannot account for all the growth and in fact there is a residual factor that comes into play and accounts For the increase in GDP. This factor is known as Total Factor Productivity. Let us try to understand it on the basis of an equation:

$$Y = A\,f(K,L)$$

Where Y is the output (GDP), K is the stock of physical capital invested and L is the labour (number of man-hours). The letter A stands for Total Factor Productivity.

In the equation given above a higher value of A means that the same inputs lead to more output and vice versa. It shows how efficiently that input is being used to further the interests of the economy and it is the productivity of the capital and labour investment. Total Factor Productivity is considered to be the actual determining factor in the growth of an economy as both capital and labour cannot continue to be invested indefinitely. Moreover the growth of economy, if depended solely on capital and labour would decline as 'soon as these investments in these inputs are reduced and vice-versa. Thus it is not a stable growth. Hence increased Total Factor Productivity is the only way that an economy can maintain a stable growth.

Also, the Law of Diminishing Marginal Returns, tells us that a sustained influx of Labour and Capital will not achieve long term growth as the value of the inputs get maximised; they onset to deliver lower returns over a period of time. Thus the only way growth can be ensured and sustained is to maximise the efficiency of these inputs and to work on improving the quality and quantity of returns for the same amount of inputs i.e. to increase Total Factor Productivity.

5.3 FACTORS AFFECTING TOTAL FACTOR PRODUCTIVITY

In the earlier section, we learnt about the fact that there is change in productivity. What are these factors that affect productivity. Some of them are:

Technological Progress – With technological progress, the inputs (R&D) are utilized efficiently and there is an increase in Total Factor Productivity. Thus inventions and discoveries in the fields of information, communication, medicine, and other areas of science & technology lead to an increase in Total Factor Productivity.

Skill levels of ***the*** workers – Skill levels of workers in a particular country cause increase in the Total Factor Productivity. Countries and also some industries with higher level of education and skills have higher Total Factor Productivity as these workers are able to produce better outputs..

Foreign Investment – Studies on TFP show that an increase in foreign investment in a country would increase total factor productivity as inputs increase provided this investment is used to promote efficiency of industry.

Natural Calamities – Natural calamities like droughts, floods, fires, etc could lead to a decrease in Total Factor Productivity as they might lead to lesser outputs for the same inputs. This is especially true of developing countries and the countries that depend a lot on agriculture as a part GDP.

Level of ***Competition*** – Literature on productivity also refers to the level of competition as an important factor determining productivity, A country with competitive markets and a strong economy would have a higher Total Factor Productivity than others that are not free market economies.

Political Stability – Factors like corruption, bureaucracy and instability lead to a decrease in the level of output. The more stable a country is, the more it increases Total Factor Productivity.

Check Your Progress 1

1) Define and explain the concept of total factor productivity.

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2) What are the factors that affect total factor productivity growth?

5.4 TOTAL FACTOR PRODUCTIVITY AND GROWTH ACCOUNTING

To reiterate, productivity is the main reason for economic growth. Some countries do better than others primarily because they are more productive. Also, the more productive a country is the better it is able to compete in the world markets as it can keep cost low while still producing a superior product. A high level of productivity also increases the standard of living of people in that country as they would get better outputs for the same inputs i.e. have better quality products at lower prices.

In order to conduct such an analysis, economists have built up a framework called growth accounting to obtain a different perspective on the sources of economic growth. Later we shall discuss that decomposing growth is essentially a growth accounting exercise. We start with a production function that tells us what output (Y_t) will be at some particular time t is a function of the economy's stock of capital (K_t), its labour force (L_t), and the economy's total factor productivity (A_t). If output changes, it can only be because of the change in the economy's capital stock, its labour force, or its level of total factor productivity. We are referring to the Cobb-Douglas form of the production function, which is:

$$Y_t = A_t K_t^{\pm} L_t^{1-\pm} \quad \ldots(1)$$

In this equation we can see that we would get higher output because of three reasons – if more number of man hours are put in (higher L), if the people have more equipment, etc to work with (higher K) or if capital and labour are used more productively (higher A). The equation at (1) shows that it assumes perfect competition and the constant returns to scale as depicted by the coefficients of K and L. If we decompose the growth in output into each of the three elements allotting 1/3rd of the increase in growth to capital and 2/3rd to labour (which is what is seen in the most developed countries), the equation then becomes

$$Y_t = A_t K_t^{1/3} L_t^{2/3} \quad \ldots(2)$$

Taking logs the growth in output (Y) is shown by the following equation

$$\ln Y = \ln A + 0.33 \ln K + 0.67 \ln L \quad \ldots(3)$$

Where lnY is the growth in output, lnK is the increase in capital, lnL is the increase in labour and lnA is the increase in Total Factor Productivity (all these are for a particular time period)

We can also use this equation to calculate growth in output per worker i.e. Labour Productivity (Y/L). This can be written as

$$Y/L = A\,(K/L)^{1/3} \quad \ldots(4)$$

When we apply the growth in output formula to this equation, it becomes

$$\ln Y/L = \ln A + 0.33 \ln K/L \quad \ldots(5)$$

Where lnY/L is the growth in output per worker, $\delta(K/L)/(K/L)$ is the increase in the amount of capital per worker and $\delta A/A$ is the increase in Total Factor Productivity.

Thus equation (5) shows that the output per worker can rise because of two reasons - increase in Total Factor Productivity and increase in the amount of capital per worker.

In order to see the effect of change in each component of this equation let us consider decomposing each component of the equation given at 3 and then see what happens

Changes in Capital

Consider, first, the effect on output of a change in the capital stock from its current value K_t to a value $K_t + \Delta K$—an increase in the capital stock by a proporlional amount $\ln K_t$. In this production function K_t is raised to apower, ±, so we can apply our rule-of-thumbfor the proportional growth rate of a quantity raised to a power to discover that the proportional increase in output from this change in the capital stock is:

$$\ln Y = \pm \ln K$$

Thus if the diminishing-returns-to-scaleparameter ± were equal to 0.33, and if the proportional change in the capital stock were 3%, then the proportional change in output would be:

$$\ln Y = 0.33 \ln K = 0.33 \times 3\% = 0.99\%$$

Changes in **Labour**

Now consider, second, the effect on output of a change in the labour force from its current value L_t to avalue $L_t + \Delta L$—an increase in the capital stock by a proportional

amount $\ln L_t$. In this production function L_t is raised to a power, 1-&, so we can apply our rule-of thumb for the proportional growth rate of a quantity raised to a power to discover that the proportional increase in output from this change in the labour force is:

$$\ln Y = (1-\pm) \ln L$$

Thus if the diminishing-returns-to-scale parameter ± were equal to 0.33, and if the proportional change in the labour force were 1%, then the proportional change in output would be:

$$\ln Y = (1-0.33) \ln L = 0.67 \times 1\% = 0.67\%$$

Changes in Total Factor Productivity

Lastly, let us see the effect on output of a change in total factor productivity. Our equation tells that a proportional increase in total factor productivity produces the same proportional increase in output:

$$\ln Y = \ln A$$

Thus if the proportional change in total factor productivity were 2%, then the proportional change in output would be:

$$\ln Y = 2\%$$

Putting Together

So if we consider a real-world situation in which all three—the capital stock, the labour force, and total factor productivity are changing—then the proportional growth rate of output is as given in equation (3), which is the key. If we know the proportional growth rates of output, the capital stock, and the labour force, and if we know the diminishing-returns-to-scale parameter ± in the production function, then we can use this growth-accounting equation to calculate the (not directly observed) rate of growth of total factor productivity A, and to decompose the growth of total output Y into (i) the contribution from the increasing capital stock K, (ii) the contribution from the increasing labour force L, and (iii) the contribution from higher total factor productivity A.

Since growth-accounting equation at (3) allows us to break down growth into components that can be attributed to the observable factors of the growth of the capital stock and of the labour force, and to a residual factor- -often, in fact, called the Solow residual or a *measure of* ignorance—that is the portion of growth left unaccounted for by increases in the standard factors of production. Changes in the Solow residual or total factor productivity can come about for many reasons explained earlier. Economists often refer to total factor productivity as "technology," but if it is technology it is technology in the widest possible sense. Not just new ways of constructing buildings, newly-invented machines, and new sources of power affect total factor productivity, but changes in work organization, in the efficiency of government regulation, in the degree of monopoly in the economy, in the literacy and skills of the workforce, and in many other factors affect total factor productivity as well.

The approach that has been used here in the measurement of total factor productivity is the so-called growth accounting, which, although being simple with respect to the computation technique, leads to sufficiently illuminating results. In growth accounting the concept 'total factor productivity' does not have a stand-alone meaning, until the influence of capital and labour is taken into consideration (and also other factors, for which statistics is available). Generally, the calculation of total factor productivity in addition to the contributions of labour and capital indicates an inability to identify or

quantify the remaining objectively existing factors, which determine economic growth, This inability most frequently stems from the lack of suitable statistical data or from the lack of preliminary studies of the values of the omitted factors. When we isolate the influences of the production factors, for which we have available statistical data, there remains the contribution of all other factors, which are generalized in literature with the term 'total factor productivity'. Moreover, the computation of the increase of the total factor productivity taking data on capital and labour is incomplete by definition, since in practice, more than two factors of growth have been identified. These include human capital, technological development and human knowledge. skills, health status, etc., which are inter-related factor having influence on economic growth.

Check Your Progress 2

1) Taking a Cobb-Douglas production function, explain how you will explain changes in output resulting from changes in capital, changes in labour and overall change in productivity.

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2) What do you understand by 'Solow residual'? Explain how total factor productivity is measured using the growth accounting method

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5.5 TOTAL FACTOR PRODUCTIVITY MEASUREMENT: DIFFERENT APPROACHES

There are two different methods to the measurement of TFP: growth accounting and econometric. Within these, there are five widely used approaches that can be categorized into three broad classes The first two, index numbers and data envelopment analysis, are flexible in the specification of technology, but do not allow for measurement errors in the data. The other three are econometric methods that calculate productivity from an estimated production function.

5.5.1 Data Envelopment Analysis (DEA)

The first approach to productivity measurement is completely nonparametric and uses linear programming. It dates back to Farrell (1957) and it was operationalised by Charnes, Cooper, and Rhodes (1978). No particular production function is assumed. Instead, the ratio of a linear combination of outputs over a linear combination of inputs is compared across observations. While there is no theoretical justification for the linear aggregation, it is natural in an activities analysis framework. This approach has some drawbacks. The flexibility in weighting can be a drawback. It has the implication that each firm with the highest output-input ratio for any combination of outputs and inputs will be considered efficient. The method is not stochastic, which is demanding on the data and makes the method sensitive to outliers. One might object to the label "100% efiicient" for the best practice firms in the sample. In some situations no firm might be efficient, e.g. due to regulation.

5.5.2 Index Numbers (TFP)

The second approach provides a theoretically motivated aggregation method for inputs and outputs, while remaining fairly sceptic on the shape of the underlying technology. According Io this approach, under a number of assumptions, it is possible to calculate the term 'A' at (1) from observables, without having to specify the exact production function, nor forcing it to be uniform across observations. The work of Solow (1957) and Diewert (1976) are considered important that refer to two types of index numbers respectively. One is Solow index and the other is Translog Index.

Solow Index

Let Y denote output (value addcd), L labour input and K capital input. Let a be the income share of capital in value addcd. Then, the Solow index of TFP is given by the following equation:

$$\ln A = \ln Y - (1-\alpha)\ln L - \alpha \ln K \qquad \ldots (6)$$

In the above equation, lnY is the growth rate of output, ln L is the growth rate of labour input and lnK is the growth rate of capital input. lnA is the growth rate of total factor productivity.

Solow index assumes the elasticity of substitution between labour and capital to be equal to one. In other words, the assumption is that if wage rate goes up by 5 per cent, then employment will fall by 5 per cent. The assumption of unitary elasticity of substitution implies that the income shares of labour and capital remain constant.

Translog index

The translog index of TFP does not make rigid assumptions about elasticity of substitution between factors of production. It allows for variable elasticity of substitution. Moreover this index does not require technological progress to be Hicks-neutral where increase in the marginal productivity of labour and capital is proportional. The translog index provides an estimate of the shift of the production function even if the technological change is non-neutral i.e. it is labour-saving or capital-saving in character.

The translog index of TFP growth is given by the following equation:

$$\Delta \ln TFP_t = \Delta \ln Y_t - [\frac{SL_t + SL_{t-1}}{2} \times \Delta \ln L_t] - [\frac{SK_t + SK_{t-1}}{2} \times \Delta \ln K_t] \quad ...(7)$$

In the above equation, Y is output, L labour and K capital. SL is income share of labour and SK denotes income share of capital. A'lnTFP is the rate of technological change or the rate of growth of total factor productivity.

One of the main advantages of the index number approach is the ease of calculation. Also, the specification of technology is flexible; allowing firms to produce with different technologies, and the method can easily handle multiple outputs and a large number of inputs.

The main disadvantages are the requirements on data quality and the assumptions regarding firm behaviour and market structure. It is impossible to account for measurement errors or to deal with outliers, except for some ad hoc trimming of the data. Factor prices information and returns to scale have to be estimated or available independently.

5.5.3 Econometric Methods

Third approach is the use of econometric methods in order to measure productivity. In the econometric approach, we apply regression analysis to estimate a production function and get the rate of technological progress from the estimated production function. The Cobb-Douglas production function is commonly been used in productivity studies. Estimation of Cobb-Douglas production function is already explained in the earlier section. Some researchers have done some variations by using different procedures such as Instrumental Variable Estimation (IVE), Stochastic Frontier Estimation (SF) and last but not the least some Semi-parametric procedures to address the issue of productivity. A detailed analysis of these methods is, however, outside the purview of this unit.

5.5.4 Limitations of Total Factor Productivity Measures

As the discussion above shows the growth accountancy method to TFP measurement is based on certain highly restrictive assumptions: constant retums to scale, perfect competition, and factors of production being paid according to their marginal product. These assumptions are not realistic, especially for a developing country where the markets are imperfect and the incomes received by factors of production are unlikely to be equal to their marginal product.

The econometric method, which is based on the estimation of production function does not require these restrictive assumptions and thus have an edge. However, this

approach also has some limitations. It assumes that same rate of technological progress for all the years under study. The estimates of the rate of technological change are often seriously affected by the problem of multi-colinearity.

Check Your Progress 3

1) Discuss the various approaches to measuring total factor productivity.

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2) Discuss the limitations of the total factor productivity measures.

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5.6 ISSUES AND DEBATES RELATED TO TOTAL FACTOR PRODUCTIVITY

There are many issues and debates related to total factor productivity. These include dichotomy between technology and capital; the slowdown in productivity; productivity and information technology and; productivity and environment.

The dichotomy between technology and capital is age-old and a vast empirical literature has attempted to sort out this dichotomy; however, without any clear consensus. A number of early studies favoured productivity as the main explanation for output growth (see Griliches: 1996). The alternative view is supported in many studies (see Young:

1995). Another issue that has received attention in literature is the slowdown in productivity particularly since late 1960s or early 1970s onwards. In India, many studies refer to the controversy on whether productivity has gone down or vice-versa during this period (For example see Goldar: 1986; Ahluwalia: 1991; Balakrishnan and Pushpangadan: 1998). This issue again has never been solved satisfactorily, despite a significant research effort.

Similarly there is debate between growth and welfare, posed by environmentalists. They argue that GDP growth overstates the actual improvement in economic welfare, but it fails to measure the depletion of natural resources and spill over of negative externalities This attack is still broadened to include the unintended consequences of industrial revolution like poverty, urban decay, displacement and so on. Another issue raised is why hasn't widely hyped information revolution reversed the productivity slowdown? This brings into picture the new economy paradox, which is largely overlooked so far in productivity studies.

5.7 LET US SUM UP

This unit dealt with total factor productivity and its growth. The unit began by defining total factor productivity. The unit then went on to discuss the factors that affect total factor productivity. Several factors from skill of workers to political stability were discussed. The subsequent topic discussed total factor productivity and growth accounting. We saw how growth in output can be explained by looking at change in capital, change in labour, and change in total productivity.

The unit also discussed the concept of Solow residual. The unit provided a detailed discussion on the various ways that productivity is measured in practice empirically, from econometric methods, data envelopment analysis method, and index number methods like the translog index and Solow index.

5.8 KEY WORDS

Growth Accounting Formula Growth accounting formula an equation that states that the growth rate of productivity equals capital's share of income times the growth rate of capital per hour of work plus the growth rate of technology.

Solow Residual Solow residual is a measure of the change in total factor productivity in a Solow growth model. This is a way of doing growth (TFP) represents output growth not accounted for by the growth in inputs.

5.9 SOME USEFUL BOOMS

Goldar, B.N. (1986) *Productivity Growth in Indian Industry*, Allied Publishers, New Delhi:

Ahluwalia, I.J., (1991) *Productivity and Growth in Indian Manufacturing*, Oxford University Press, Delhi.

Biesebroeck, J.V., (2003) "Revisiting some Productivity Debates". NBER Working Paper No. 10065.

Nadiri, M.I., (1970) "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey", *Journal of Economic* Literature, December.

Balakrishnan, P., and Pushpangadan, K., (1998) "What Do We Know about Productivity Growth in Indian Industiy," *Economic and Political Weekly*, August *15-22*.

5.10 ANSWERS/HINTS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1) Read section 5.2 and answer.

2) Read section 5.3 and answer

Check Your Progress 2

1) Read section 5.4 and answer.

2) Read section 5.4 and answer.

Check Your Progress 3

1) Read section 5.5 and answer.

2) Read Sub-section 5.5.4 and answer.