Subject	ECONOMICS
Paper No and Title	**12:Economics of Growth and Development**
Module No and Title	**13: Technical Changes and Progress: Learning by Doing**
Module Tag	**ECO_P12_M13**

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1. Learning Outcomes

After studying this module, you shall be able to

- Know about basics of Technical change, process affecting technical change.
- Learn about the evolution through which technical change takes place.
- Identify the role of Ideas, experience, Institutions, Incentives to facilitate the environment of Technical Change.
- Different Models try to explain the process of Technical change.

2. Introduction

Technological changes are counted as the most important factor in the process of economic growth. They are mostly referring as the change in mode of production through new technique emerges out from research or innovation. Changes in technology lead to increase in productivity of labour, capital and other factors used in production. Schumpeter regards innovation as most important technological factor in economic growth.

Modern economic growth theories even assume that without technical progress, a country cannot sustain the growth in per capita income indefinitely. Due to low technological progress in least developed countries they are not able to break the vicious circle of under-development. Developed countries are succeeded in continuous adaptation of new technology due to higher spending in research and development activities.

The importance of technical change acknowledged in the process of economic growth. Technical change is key factor in affecting productivity of factor of production used in the production. It's often described a two-staged dynamic process; (1) creation of new Knowledge and technology and (2) the adoption of new technology. The creation of new technology and adoption of associated new technology is stimulated by expenditure on research and development. A distinction often made in the literature concerns the source of funding for R&D, often referred as, public versus private. When new technology has the characteristics of a public good, then public funding of research may require. On the other hand, when property rights for technology can be privately assigned and enforced, then private institutions can have the proper incentives to invest in R & D[1].

[1] Jean-Paul chavase et al(1997): "An Analysis of source and nature of Technical change: The Case of US Agriculture", *The Review of Economics and Statistics*, Vol-70(3).

3. Nature and Characteristics of Technical Change

In the world of economics engaged with process of growth and development; technology refers the process through which inputs transformed into the output. For instance if we have production function Y = A *F* (K, L,) then the *F* (.) explains how inputs are transformed into output. The primary component in developing technology is idea. New set of idea allow using same inputs or new inputs to produce more amount of same goods or different goods with better qualities. In the cited production function new idea led to changes in A. Paul Romer explains the relationship between economics of ideas and economic growth. According to him, the very characteristics of ideas are that they possess the non rivalrous nature. This non-rivarly nature ensures the presence of increasing return to scale.

The other important characteristics of idea relates with degree of excludability. The degree to which a good is excludable depends on how much the owner of the good can charge a fee for its use. For example, copyrights and patent system are the tools through which an owner of ideas can charge a fee for allowing to use the idea.

As Charles Jones writes in his book ideas are non rivalrous goods but they vary substantially in their degree of excludability. Encoded satellite TV transmissions are highly excludable, whereas computer software are less excludable. Non rivalrous goods that are usually defined as unexcludable are often called public goods. A traditional example is national defense. Some idea may also be both non rivalrous and unexcludable. For example, calculus, our scientific understanding of medicine is few to mention here.

Goods that are rivalrous must be produced each time they are sold; goods that are non rivalrous has to be produced only once. In other words, we can conclude that non rivalrous goods like ideas only require a fixed cost of production and zero marginal cost. For example, it costs a great deal to produce the first unit of latest word processor or spreadsheet, but once it produced the later units can be produced by simply copying the software from the first unit. Other example which more relevant here is it required great deal of inspiration and effort for Thomas Edison and his lab to produce the first commercially viable electric light. But once the first light was produced, additional light could be produced at much lower cost and lesser effort[2].

The next question posed what incentive one has in developing new ideas. The answer lies in that ideas are closely associated with incentives of increasing return to scale and imperfect competition. Since to generate ideas investment require till ideas are not fully developed for application. To develop ideas a fixed cost are associated with it. For example, to develop a fifth generation processor for laptop require a onetime research cost. Once the product is developed the later units can be produced cheaply.

[2] Charles I. Jones (2006): "Introduction to Economic Growth", *ViVa Book Private Limited,* New Delhi.

Here we can cite a example given by C.I. Jones. Let a production function faces firm is given by y = f(x) = 100* (x- F) that exhibits a fixed cost F and a constant marginal cost of production. Let y denotes the copies of next generation processor for laptop and assume x is amount labour inputs require in the production. In the example, F units of labor required to produce the first unit of next generation processor. Here, F represents the research cost, likely to be very high. If x is measured as hours of labor inputs, and let assume F = 10,000: it takes 10,000 hours to produce first unit of next generation processor. After the first unit is created, additional unit can be produced at very lower cost. In our example, one hour of labor input can produce 100 copies of the processor. Since production function exhibits the increasing return to scale. F units of inputs are required before any output can be produced; 2F units of units will produce 100*F units of output. The increasing return to scale can also observed in increasing labour productivity i.e. y/x.

The other characteristics associated with economics of ideas are presence of imperfect competition. Since presence of increasing return to scale make it necessary to charge a price higher than marginal cost otherwise firm would incur negative profits. With increasing return to scale, average cost is always greater than marginal cost and therefore marginal cost pricing results in negative profits. It refers that no firm would enter the market and spend F fixed cost to develop the processor if it could not set the price above the marginal cost of producing additional units. The production of new goods, or new ideas, requires the possibility of earning profits and that why necessitates moving away from perfect competition[3].

We have discussed in detail about economics of idea preceded high investment in R & D. unless inventors have some surety or expectation about getting some gain after creation of ideas they would refrain from venturing out to create new ideas. Here, patents and copyrights are the some legal mechanism through which inventor can be assured to reap some benefits after creation of invention. Such mechanism guarantee monopoly power over invention to use for certain period until inventor can recover cost and desired profits. Patents or copyrights are used to influence the degree of excludability of idea; otherwise there would be possibility of imitation which led to elimination of incentive for innovator to create the ideas in the first place.

The sustained economic growth is a very recent phenomenon. For instance, consider the growth rate of world leaders over the past four centuries. During the period 1580-1820, the Netherlands was the leading industrial nation it experienced an average annual growth in real GDP per worker hour of roughly 0.2 percent. The UK, leader during the approximate period 1820-90, experienced an annual growth of 1.2 percent. Since 1890, the US is considered to have usurped the leaders' seat, and its average growth rate during the period 1890-1989 was a relatively dramatic 2.2 percent a year. Clearly, by today's standard even the fastest growing economy two centuries ago would be considered practically stagnant. According to one estimate, even the modest 2 percent growth, a nation's per capita GDP doubles in 35 years[4].

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[3] ibid

[4] Debraj (1998): "Development Economics", pp. 47-50, *Oxford University Press*.

Economic historian Douglas C. North tried to explain the reason behind the sustain growth as a recent phenomenon; he wrote raising question what determines the rate of development of new technology and of pure scientific knowledge? In case of technological change, developing new techniques led to high social return but until it can be assured that the private rate of return on developing new techniques is high; there would be always changes of slow progress in creating new ideas. He further said it has been found that throughout the human history, new techniques are developed but the pace has been slow and intermittent, and such innovation can be copied by other without any fee to innovators. The failure to develop a legal protection in innovation up until fairly modern times was a major source of slow pace of technical change.

It is evident from recent data of technical progress reason behind the sustained increased in economics of ideas. For instance, in US alone during 1880 approximately 13,000 patent were issued; in 1999, more than 150,000 patent were issued. Presumable, number of ideas used in the US economy increased substantially over the century. Similarly, number of scientist and engineers engaged in R&D increased from 200,000 to nearly 1 million between 1950 to1993[5].

4. Learning By Doing

Learning by doing has played a central role in endogenous growth theory ever since Arrow (1962) used this concept. He conceptualized learning by doing within the actual activity of production, with cumulative gross investment as the catalyst for experience. Later Lucas (1988) tried to explain role of experience as a factor increasing the productivity growth. In Lucas word's, "in the-job-training or learning by doing appear to be at least as important as schooling in the formation of human capital".

Empirical studies have confirmed the importance of learning by doing. For instance, Lundberg (1961), who studied the experience of the Horndal Iron works plant in Sweden. He found out that during over 15 years, plant had no new investment yet output per worker rose about 2 percent annually. Another important observation of learning by doing phenomenon have found in aircraft industry. As studies shows that labor inputs per airframe declined significantly yet the total number of airframes produced increased[6]. Progress of this kind observed across the industries often caused by adaptation efforts by labor.

The Arrow Model- Arrow was the first one to introduce nature of technological with the help of learning by doing concept. He proposed that at any amount of time new capital goods incorporate all the knowledge then available based on accumulated experience, but once built, their productive deficiency cannot be changed by subsequent learning.

[5] Charles I. Jones (2006): "Introduction to Economic Growth", pp.78-93, ViVa *Book Private Limited,* New Delhi.

[6] Middleton (1945): "Wartime Productivity changes in the Airframe Industry", Monthly Labour Review, 61(12):215-225.

Arrow mentioned two major factor determining learning by doing concept in his article. First, according to him learning is the product of experience. Learning can only take place through the attempt to solve a problem and therefore only takes place during activity. Second, he argued that learning often associate with repetition of essentially the same problem is subject to diminishing return. To have steadily increasingly performance, there should be stimulus situation steadily evolving rather than merely repeating.

In production function form it can be written as

$$Y_i = A(K)F(K_i, L_i,)$$

Where Y denotes the output of firm, K denotes the stock of capital, L denotes the stock of labour, A is the technology factor. K without subscript denotes the aggregate stock of capital. He showed that if the stock of labour is held constant, growth ultimately comes to a halt because social very little is invested and produced.

The Romer Model- Romer has attempted to present kind of technical change determined by learning by investment. He assumed that creation of knowledge as a side product of investment. He takes knowledge as a input in the production function of the following form

$$Y = A(R)\ F\ (R_i, K_i, L_i)$$

Where Y is output, A is the public stock of knowledge from research and development R; R is the stock of knowledge from expenditure on research and development; K and L are capital and labour stock.

Romer took three key elements in his model, namely externalities, increasing return in the production of output and diminishing return in the production of new knowledge. According to Romer, it is spillovers from research efforts by a firm that lead to the creation of new knowledge by other firms. In other words, new research technology by a firm spillsover instantly across the entire economy.

In his model, new knowledge is the ultimate determinants of long-run growth which is determined by investment in research technology. Research technology exhibits diminishing return which means that investments in research technology will not double knowledge. Moreover, the firm investing in research technology will not be exclusive beneficiary of the increase in knowledge. The other firms also make use of the new knowledge due to inadequacy of patent protection and increase their production. Thus the production of goods from increased knowledge displays increasing aggregate returns owing to externalities. Thus Romer takes investment in research technology as endogenous factor in terms of the acquisition of new knowledge.

The Lucas model- Lucas assumes that investment on education leads to the production of human capital which is a crucial determinant in the growth process. he makes a distinction between the internal effects of human capital where the individual workers undergoing training becomes more productive , and external effects which spillover and spillover and increase the productivity of capital and of other workers in the economy. It is investment in human capital rather than physical capital that have spillover effect that increase the level of technology. Thus the output for firm takes the form

$$Y= A (K_i) (H_i) H^e$$

Where A is the technical coefficient, K and H are the inputs of physical and human capital used by firm to produce goods Y. the variable H is economy's average level of human capital. The parameter e represents the strength of the external effect from human capital to each firm's productivity.

In the Lucas model, each firm faces constant return to scale, while there are increasing returns for the whole economy. Further, learning by doing or on-the-job training and spillover effects involve human capital. Each firm benefits from the average level of human capital in the economy, rather than from aggregate of the human capital. Thus it is not the accumulated knowledge or experience of other firms but the average level of skills and knowledge in the economy that are crucial for economic growth.

5. Summary

- Modern economic growth theories even assume that without technical progress, a country cannot sustain the growth in per capita income indefinitely. Technical change is key factor in affecting productivity of factor of production used in the production.
- The primary component in developing technology is idea. New set of idea allow to use same inputs or new inputs to produce more amount of same goods or different goods with better qualities
- Characteristics of ideas are that they possess the non rivalrous nature.
- The other important characteristics of idea relates with degree of excludability.
- ideas are closely associated with incentives of increasing return to scale and imperfect competition
- Patents and copyrights are the some legal mechanism through which inventor can be assured to reap some benefits after creation of invention.

- Empirical studies have confirmed the importance of learning by doing concept in bringing technological change.
- Arrow proposed that at any amount of time new capital goods incorporate all the knowledge then available based on accumulated experience, but once built, their productive deficiency cannot be changed by subsequent learning.
- Romer took three key elements in his model, namely externalities, increasing return in the production of output and diminishing return in the production of new knowledge. According to Romer, it is spillovers from research efforts by a firm that lead to the creation of new knowledge by other firms. In other words, new research technology by a firm spillsover instantly across the entire economy.
- According to Lucas it is investment on education that leads to the production of human capital which is a crucial determinant in the growth process.

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