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Semester V – Industrial Economics

**Unit 5**

# TECHNICAL PROGRESS AND PERFORMANCE

## Part 3

**Topics covered: Importance of firm size in innovation, role of technical progress in economic growth, growth accounting, and concept of profitability, productivity and technical efficiency**

## Introduction

At the micro-economic level, improvements in technology can be the result of the search for efficiency by individual operators seeking to increase profitability, which if successful then spreads through the community. Key macro-economic conditions may also bring about changes in the use of technology. These macro-level conditions include factors such as the expansion of international and domestic markets, exposure to international practices and greater communication and knowledge of other areas of the world and liberal policies. All of these might be termed "enabling" conditions. They may also be the result of necessity, supporting the adage that "necessity is the mother of invention".

This session discusses the impact of firm size and innovation. Though the debate is not constructively conclusive but the arguments in favor and against are discussed with their relative impact on innovation and subsequently technical progress.

**Firm size and innovation**

There are also other characteristics of small and large firms, which may represent an advantage as well as a disadvantage. For instance while the presence of fewer hierarchical layers in smaller firms may on the one hand reduce bureaucracy, increase flexibility and result in less filtering of proposals, it also limits career opportunities for their employees. Less filtering of proposals can result in very original ventures, or a fatal lack of opposition to misapprehensions. Or while craftsmanship may yield unique or scarce competencies, it can also result in a lack of attention for marketing and financial planning.

Most empirical findings suggest that small and medium-sized firms, rather than large firms, conduct R&D more efficiently. Also small firms and independent inventors are disproportionately responsible for significant innovations there are however other, complementary explanations for the empirical finding that small firms have much more innovative output than one would expect on the basis of their innovative input. First, small firm R&D tends to be underestimated in many standard surveys, because mainly formal R&D, conducted in separate R&D departments is measured. Moreover, studies of the different components of innovation costs indicate that larger firms have higher shares of R&D in total innovation costs than smaller firms, so that independently from the way it is measured, R&D would underestimate the innovative input of smaller firms. Secondly, it is indicate that small firms more effectively take advantage of knowledge spillovers from corporate R&D laboratories and universities. And third, the economic value of innovations may differ between smaller and larger firms, as under certain stochastic conditions, larger firms will produce fewer innovations per dollar spent on R&D, but their innovations will be on average of a higher quality.

From the stylized fact that smaller firms produce more innovations than one would expect on the basis of their input, It concludes that apparently organizational diseconomies of scale outweigh the technological economies of scale in R&D. The aforementioned explanations and the organizational characteristics related to size mentioned in the last paragraph suggest however, that it is not either small firms or large firms which are the better innovators per se.

Instead, small and large firms are probably good at different types of innovation, or their roles vary over the industry cycle. Large firms are probably better at the kind of innovations that make use of economies of scale and scope, or require large teams of specialists, such as fundamental, science-based innovations and large scale applications, which are probably also the innovations with higher average economic value. Small firms are likely to be relatively strong in innovations where effects of scale are not (yet) important and where they can make use of their flexibility and proximity to market demand, such as new products or product market combinations, modifications to existing products for niche markets, and small-scale applications. Moreover, the small firms' efficiency in producing these kinds of innovations is enhanced by their ability to take advantage of knowledge spillovers from large firms' corporate R&D departments.

**Technical efficiency**

Technical efficiency is the effectiveness with which a given set of inputs is used to produce an output. A firm is said to be technically efficient if a firm is producing the maximum output from the minimum quantity of inputs, such as labor, capital and technology.

**Productivity**

Productivity growth is seen as the key economic indicator of innovation. The successful introduction of new products and new or altered processes, organization structures, systems, and business models generates growth of output that exceeds the growth of inputs. This results in growth in productivity or output per unit of input. Income growth can also take place without innovation through replication of established technologies. With only replication and without innovation, output will increase in proportion to inputs.

Productivity is a measure of output per unit inputs. It is a physical concept. Profit is a measure of receipts minus costs. It is a financial concept. Both concepts are important when evaluating the health of an industry. They analyses different aspects of performance. All else held constant, a productivity improvement will increase profit, through its effect on the way inputs are transformed into outputs: more output (and hence revenue) will be produced from the same inputs (same costs). Usually, productivity improvement occurs over a period of time (like 5 to 10 years). This means it will be happening concurrently with other changes. For example, output prices may be falling relative to input prices. If the latter effect is very large, it may negate or overturn the positive effect that a productivity improvement would have had on profit. Conversely, if output prices are rising relative to input prices, then this will enhance the effect of a productivity improvement, giving a firm two sources of profit gain over the relevant time period.

This session explains the role of technical progress in sustained economic growth. Economists since Schumpeter have argued about the importance of technological changes in total productivity and sustained growth. This unit explains the Solow's model where technological progress is proved empirically to bring growth in developing economies.

**Economic growth**

Economic growth is a sustained increase, over a significant period, in the quantity of material goods and services produced in an economy.

**Measurement of growth**

Economic growth is measure by using data on GDP, which is a measure of total income earned by the people of a country through their participation in the production process.

**Economic growth facts**

Solow model of economic growth reflects the given key empirical regularities;

1. Before the industrial revolution which started around 1800, standards of living didn’t differ much among countries over time and across countries.
2. Since the time of the industrial revolution, per capita income growth has been sustained in the richest countries.
3. There was a strong positive correlation between the rate of investment and output per capita across countries.
4. Negative correlation between the population growth rate and the output per capita across countries.
5. Differences in per capita incomes increased dramatically among countries of the world between 1780 and 1950.

6. No correlation was found across countries between the level of output per capita in 1960 and the average rate of growth in output per capita for the years 1960-2000.
7. Richer countries are much more alike in terms of rates of growth of real per capita income than poorer counterparts.

**Growth accounting approach**

During the 20th century the rate of economic growth in developed countries has accelerated and the sources of growth have changed. It is attributing the growth in GDP to growth in factor inputs and in total factor productivity.

A few studies made in the 1950's established the rates of economic growth prevailing in the 20th century were much higher than could be explained by combined growth of labor and capital inputs. Thus J.W. Kendrick (1961) has defined unexplained residual growth as growth in total factor productivity (TFP). The discovery of the residual growth stimulated interest in the technological change as a source of growth and gave rise to economic research on innovations, on the effects of research and development (R&D) activities, and on inter industry and international transfers of technology. It also gave rise to growth accounting (GA), an approach developed by E. Dension (1974) and others. The GA seeks to assess quantitatively the contribution made to economic growth in quantity of labor and capital inputs and growth in productivity. According to the GA approach, growth in output can be divided into three components.

- Growth in labour force
- Increase in stock of capital
- Technological progress

These are known as the source of growth. The decomposition of the components of growth enables us to measure the rate of technological progress.

According to GA approach, growth is of two types;

- Extensive growth occurs due to increase in capital and labour.
- Intensive growth occurs due to increase in TFP caused by technological progress.

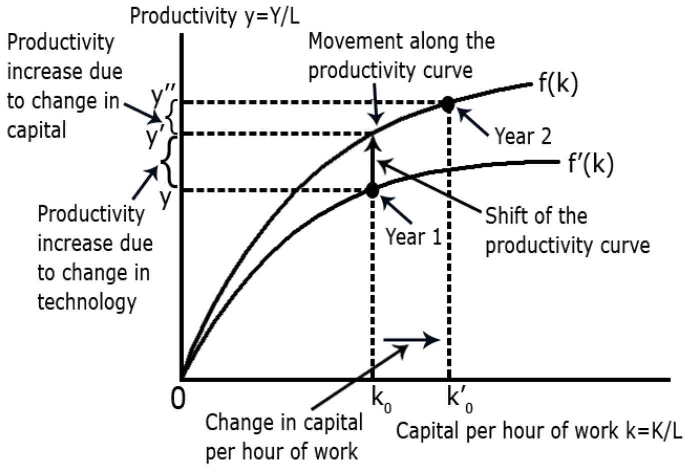
**Intensive growth caused by rise in TFP**

The growth accounting formula splits up the growth of productivity into two sources:

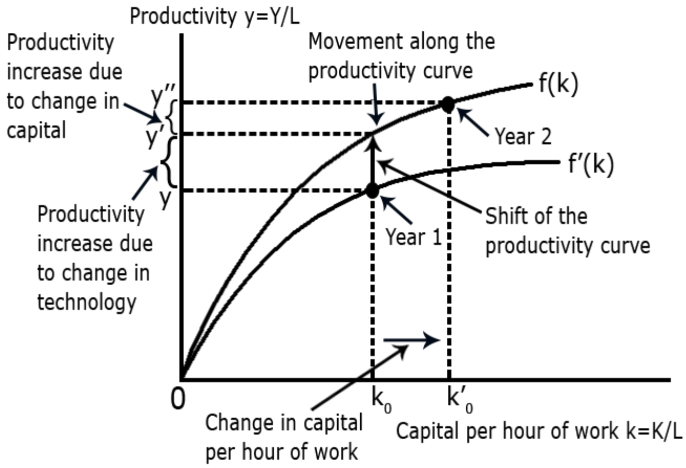
- The growth of capital per hour of work
- The rate of technological progress

The figure shows the relationship between productivity (*Y/L*) and capital per hour of work (*K/L*). Higher capital per hour leads to more output per hour, as shown by the two production functions.

Technological progress shifts the original production function *f(k)* upto *f'(k)* because as technology improves over the time the productivity of a given level of capital per hour of work rises.




Actual productivity increases in any economy are due to a combination of movements along the productivity curve, because of more capital per hour, and or shifts of the productivity curve, because of technological progress. The main purpose of the GA approach is to determine how much output gain is due to movement along the curve and how much is due to a shift. This is illustrated by two observations on productivity and capital per hour in two different years (year 1 and year 2). It is seen how the increase in productivity from year 1 to year 2 is due to partly to an upward shift of the production function curve and partly to a movement along the function.




Solow observed that technological progress had the effect of improving the production function by shifting it upward over time. This virtually amounts to raising the productivity of existing resources. We say that there is a rise in productivity if it is possible to produce the same amount of output with fewer inputs or more output with the same amount of inputs. This figure shows that it is possible to produce more output (*yy'*) from the same amount of capital per worker ($k_0$). This virtually amounts to raising the $MP_{k.}$

The aggregate production function will be ;

Y=AF (K,L)

Where Y, K and L are standard notations and A is the measure of the current level of technology. It is the efficiency parameter of the production function showing the effect of an increase in TFP. Output increases not only due to increase in capital and labor (extensive growth) but also due to increase in TFP (intensive growth). So the distinction is between movement along the same production function and shift of the production function due to increase in TFP. Even if inputs remain unchanged but Y increases by 25 the TFP must have increased by 2%.

Now economic growth can be expressed as:

$$\frac{dY}{Y} = \alpha\frac{dK}{K} + (1-\alpha)\frac{dL}{L} + \frac{dA}{A}$$

Or,

$$\text{Growth in output} = \text{Contribution of capital} + \text{Contribution of labour} + \text{Growth in TFP}$$

Thus, according to the GA approach, there are three sources of growth as are captured by the key equation, viz.

- Changes in the amount of capital
- Changes in the amount of labor
- Changes in TFP.

Since data on TFP are not readily available, we compute the growth in TFP by subtracting the first two terms on the r.h.s of equation from the l.h.s.

In this context dA/A is called the residual factor of growth in the sense that it cannot be explained by systematic changes in inputs. But it may be attributed to random variables such as a favorable technological change. Thus if 65% of a country’s growth is accounted for by the growth of labor force and capital stock, the it logically follows that the remaining 35% of its economic growth is due to increase in TFP. E.

Denison called it a measure of our ignorance. Modern economists call it the Solow residual because it was R.M. Solow who first showed how to compute it. In fact in terms of the Solow model, we find a close relation between growth in labor efficiency (E) and growth in TFP.

In Solow's model here (1-$\alpha$) is labor's share in total output.

Thus technological change, as measured by the growth in the efficiency of labor, is proportional to technological change as measured by the Solow residual i.e. dA/A (here $\alpha$ is the proportionality factor).

Since increased knowledge about production method due to more investment in worker education and training often raises TFP, the Solow residual is often used as a measure of technological progress. Anything which alters the relation between measured inputs and measured output will have an effect on TFP. For example if the firm installs a new pollution control equipment, $MP_k$ will fall and TFP will fall too.

**Theory and evidence**

Sources of productivity growth and reasons for change have not yet been successfully isolated. However economic research has pointed out that business expenditures for research and development were consistently found to be positively associated with the increases in output per unit of input in a large number of cases. Periods of severe recession or of large variation in output coincided with periods of slower growth in productivity.

From this it is understood that economists can calculate or measure the coefficient of capital growth in the growth accounting formula with much precision. There is uncertainty about its size though.

In any case, the growth accounting formula is a helpful rule of thumb to assist policy makers in deciding what emphasis to place on capital versus technology when undertaking programs to stimulate economic growth.

**Prediction**

Unless productivity growth accelerates in the future it is apprehended that prolonged periods of slow growth in real earnings and in per capita income will result. This will lead to deterioration in living standards even in advanced countries, not to speak of developing countries in the years to come.

**Solow's analysis**

The Solow model shows how nations grow through the interplay of saving, population growth and technological progress.

- He has proved conclusively that (1) capital formation (2) growth of labor force and (3) technological progress conjointly affect the level of an economy's output and tis rate of growth of per capita income over time.
- His original model could not explain the observed sustained growth in most countries of the world. He had considered four variables:

Output (y), Capital stock (k), labor force (L) and knowledge (E)

He excluded the possibility of technological progress. The only source of economic growth in the Solow model was revealed to be capital accumulation. High rates of saving and capital accumulation lead to high growth for some time. But the economy eventually reached a steady state in which both capital and output remained constant.

So later other variables i. population growth and ii. Technological progress were considered and those could explain sustained growth and profitability.

**Solow's model with technical progress**

Technical progress is the application of technological changes for improved productivity, output and profitability of the firm. Continuous R & D gives such firms a competitive edge. It increases output directly by raising the productivity of resources (capital and labor).

Hence 'knowledge (E)' which was taken as efficiency of labor in the former model was later considered as a product of labor force and increase in efficiency (L*E). This measured the number of effective workers. The underlying assumption was that technological change was labor augmenting.

With the incorporation of technological progress, the Solow model could surely explain the sustained growth and its ability to raise the standard of living in the advancing world.

**Policy prescription**

The main policy approaches for raising productivity growth concern stimulation of investment in modern fixed capital, training and education, social infrastructure and technological development as well as economic stability. Various policies encourage public and private participation so far allocation of resources to product and process innovation. The question now arises regarding the interest of the firms and the market structure which determines the intensity of inventive activities. The Patent system is a good method to protect the inventor's inventions for a specified time period so that he gets an opportunity to cash on technical efficiency and profitability. Government too can promote industries that are carriers of technological progress. They are called sunrise industries.

**Criticism**

Solow's model considers technological progress as exogenous. It does not explain in truth, the determinants of technological progress. According to Paul Romar, the technological change is endogenous. It means that growth of technology is assumed to depend on growth of capital.

**Summary**

A significant relationship between size and technical efficiency is assumed to be present. Though empirically it is proved over time that there are at least two reasons for expecting a negative relationship between size and efficiency. First, large firms may suffer more from bureaucratic frictions, lack of motivation of workers, and difficulty in monitoring than smaller firms. Second, large firms are more able to remain in the market even if they have economic problems due to a low technical efficiency than small firms because of the existence of market imperfections. Due to this effect of market selection, the surviving small firms may on average show a higher level of technical efficiency than the larger firms do.

The R&D intensity, affects positively the firm's efficiency, that is, innovative firms tend to be closer to the frontier than those firms that do not perform R&D spending. It is conclusive that the most innovative companies are closer to the efficient frontier than those that are not innovative.

To sum up, the impact of the investment in R&D over efficiency. Productivity and profitability has been positive and statistically significant. This implies that all policies conducted to incentive this kind of investment will contribute to a productivity growth in the long run.