UNIT 6 ENDOGENOUS GROWTH MODELS*

Structure

6.0 OBJECTIVES

After going through the Unit, you will be able to:

- Describe the emergence of Endogenous growth models;
- List the assumptions of endogenous growth models;
- Analyse the basic ideas on which these models rest and function in the context of real world;
- Discuss and evaluate the working of endogenous growth models;
- Identify the limitations of these models; and
- State the policy implications of these models.

6.1 INTRODUCTION

Endogenous growth theory was developed as a reaction to omissions and deficiencies in the Solow (neoclassical) growth model. It is a new theory which explains the long run growth rate of an economy on the basis of endogenous factors as against exogenous factors of the neoclassical growth theory.

The new growth theory of the 1990s was labeled "endogenous growth theory" because it attempted to explain technical change as the result of profit-motivated research and development (R&D) expenditure by private firms. This was driven by competition along the lines of what Schumpeter called product innovations (as distinct from process innovations). In contrast to the Harrod-Domar model,

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which viewed growth as exogenous, or coming from outside variables, the endogenous theory emphasizes growth from within the system. This approach enjoyed, and still enjoys, an enormous vogue, partly because it seemed to offer governments a new means of promoting economic growth—namely, national innovation policies designed to stimulate more private and public R&D spending.

While the neo-classical growth models explain the long run growth rate of output based on exogenous variables namely rate of growth of population and rate of growth of technical progress (independent of savings rate), the new growth theory extends this by introducing endogenous technical progress in growth models. The Endogenous growth models emphasize on technological progress resulting from the rate of Investment, size of capital stock and stock of human capital. The concept of economic growth here is thus, internal to the economy. The theory is built on the idea that the improvements in innovation, knowledge and human capital lead to increased productivity, positively affecting the economic outlook.

The Endogenous growth theory challenges the idea of predicting growth without incorporating technological advancements. Since economic growth is derived from the growth rate of economic output per person, it would depend on the productivity levels and these would in turn depend on the progress of technological change. The endogenous growth theory considers these factors *viz*. innovation and human capital as internal to the economy.

Models of Endogenous growth bear some structural resemblance to their neoclassical counterparts but they differ considerably in their underlying assumptions and conclusions drawn. The most significant theoretical differences stem from discarding the neoclassical assumptions of diminishing returns to capital investments, permitting increasing returns to scale in aggregate production and frequently focusing on the role of externalities in determining the rates of return on capital investments. By assuming that public and private investments in human capital generate external economies and productivity improvements that offset the natural tendency for diminishing returns, endogenous growth theory seeks to explain the existence of increasing returns to scale and the divergent long-term growth patterns among countries. While technology still plays an important role in these models, exogenous changes in technology are no longer necessary to explain long run growth.

The new growth theory reemphasizes the importance of savings and human capital investments for achieving rapid growth just like Harrod-Domar model, but it leads to several implications for growth that are in direct conflict with traditional theory: a) there is no force leading to the equilibration of growth rates across closed economies, it remains constant or differs according to savings rates and technology levels and b)there is no tendency for per capita income levels in poor countries that are capital scarce to catch up with rich countries. The best part about this theory is that it seeks to explain the anomalous international flows of capital that exacerbate wealth disparities between rich and poor countries.

The potentially high rates of return on investment offered by developing economies with low capital-labour ratios are greatly eroded by lower level of complementary investments in human capital (education and health), infrastructure of R&D. Hence, poor countries benefit less from the social gains associated with these. Since individuals do not internalize these gains by positive externalities, the free market leads to sub optimal accumulation of complementary capital in the society. The state can play a key role here by improving the efficiency of resource allocation by provision of public goods/infrastructure and encouraging private investments in knowledge-intensive industries where human capital can be accumulated.

6.2 ASSUMPTIONS OF NEW GROWTH THEORIES (ENDOGENOUS GROWTH MODELS)

In general, the new growth theories rest on the following basic assumptions

- There are many firms in the market.
- Technological advancement or knowledge is a non-rival good.
- Increasing returns to scale to all factors taken together prevails when constant returns to a single factor exists.
- Technological advancements come from things people do. It is based on creation of new ideas.
- Increasing returns to scale in production leads to imperfect competition and thus, many individuals and firms have market power and earn profits from their discoveries.
- Emphasis is on the need of the Government to provide incentives and subsidies for businesses in the private sector.
- Investments should also be made to improve infrastructure and manufacturing processes to achieve innovation in production.

Check Your Progress 1

1. How does endogenous growth theory explain persistent growth without the assumption of exogenous technological progress How does this differ from the Solow model?

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2. How is endogenous growth different from exogenous growth?

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6.3 ENDOGENOUS GROWTH MODELS

6.3.1 Arrow's Theory of Learning-by-doing

Learning-by-doing is a concept in economic theory by which productivity is achieved through practice, self-perfection and minor innovations. Kenneth Arrow used this concept in his design of Endogenous growth theory to explain the effects of innovation and technological change. Arrow's classical paper "The Economic Implications of Learning by doing" published in 1962 showed how this idea fits into the modern theory of economic growth and used it as a springboard for a critical consideration of spectacular recent developments. He introduced the increases in per capita income that cannot be merely explained by increases in capital-labour ratio. Identifying the role of technological change in economic growth and providing an explanation of the concept of knowledge which underlies a production function, he examined how knowledge has to be acquired.

He therefore suggested an endogenous theory of the changes in knowledge which underlie inter-temporal and international shifts in production functions. The acquisition of knowledge called "learning" might be interpreted in different ways yet it accepted by all schools of thought; learning is a product of experience. It can only take place through the attempt to solve a problem and therefore, takes place only during an activity. He generalized from many of the classical learning experiments that learning associated with repetition of essentially the same problem is subject to diminishing returns. There is an equilibrium response pattern for any given stimulus, towards which the behaviour of the learner tends with repetition. To have steadily increasing performance, then, implies that the stimulus situations must themselves be steadily evolving rather than merely repeating.

He emphasized the role of experience in increasing productivity that had yet to be absorbed into the main corpus of economic theory. He thus, advanced the hypothesis that technological change in general could be ascribed to experience that is the very activity of production which gives rise to problems for which favourable responses are selected over time. Hence, learning by doing is an example of knowledge accumulation from the production process. As individuals produce goods, ways of improving production processes happen inevitably. The improvement in productivity occurs as a byproduct of normal production activity and not as a result of deliberate efforts.

When learning by doing is the source of technological progress, the rate of growth/accumulation of knowledge depends not on the proportion of GDP devoted to R&D but from how much new knowledge is generated by traditional productive activity. The production function can be written as

$$Y(t) = K(t)^{\alpha} [A(t)\, L(t)]^{1-\alpha} \quad \text{----------(1)}$$

Where K=Capital, L=Labour, Y=Output, A=Stock of knowledge and α = a parameter that lies between 0 and 1

The simplest case of learning by doing is found in those situations where learning occurs as a side effect of the production of new capital. Since, the increase in knowledge is a function of increasing capital, the stock of knowledge is a function of the stock of capital. There is only one stock variable whose behaviour is endogenous here

$A(t)=B\,K(t)^{\beta}$ B and β are both greater than 0 --------(2)

If we put this in Equation (1) we get

$Y(t)=K(t)^{\alpha}\,B^{1-\alpha}\,K(t)^{\beta(1-\alpha)}\,L(t)^{1-\alpha}$

In the presence of learning, the contribution of capital is larger than its conventional contribution: increased capital raises output not only through its direct contribution to production [term $K(t)^{\alpha}$] but also by indirectly contributing to the development of new ideas and making all other capital more productive [term $K(t)^{\beta(1-\alpha)}$].

In a simplified form, the model is represented as the following:

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

Where for a firm i

Y_i is output, K_i is the aggregate stock of capital and L_i is the stock of labour

A is the technical factor and K represents the aggregate stock of capital

6.3.2 The Levhari-Sheshinski Model

Levhari and Sheshinski have generalized and extended Arrow's model. They stress on the spillover effects of increased investment as the source of knowledge. They assume that the source of knowledge or learning by doing is each firm's investment. An increase in a firm's investment leads to a concomitant increase in its level of knowledge. An increase in a firm's investment leads to a parallel increase in its level of knowledge. The model assumes that the knowledge of a firm is a public good which other firm can have at zero cost. Thus, knowledge has a non-rival character which spills over across all the firms in the economy. This is when each firm operates under constant returns to scale and the economy as a whole is operating under increasing returns to scale.

This model explains endogenous technological progress in terms of knowledge or learning by doing that is reflected in an upward raising of production function and economic growth in the context of aggregate increasing returns being consistent with competitive equilibrium.

6.3.3 The King-Robson Model

King and Robson in a paper published in 1993 emphasised learning by watching in their technological progress function. Investment by a firm represents innovation to solve the problems it faces. If it is successful, the other firms will adopt the innovation to their own needs. Thus, externalities resulting from learning by watching are a key to economic growth. This study shows that

innovation in one sector of the economy has the contagion or demonstration effect on the productivity of other sectors, thereby leading to economic growth. Multiple steady state growth paths exist, even for economies having similar initial endowments and policies that increase investment should be pursued.

6.3.4 Romer Model

Romer in his first paper on endogenous growth in 1986 presented a variant on Arrow's Model which is known as learning by investment. He assumed creation of knowledge as a side product of investment. He took knowledge as in input in the production function of the following form:

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

Where Y = Aggregate output, A(R) = public stock of knowledge from R&D

R_i = stock of results from expenditure on R&D by firm i , K_i = capital stock of firm i and L_i = labour input of firm i

He assumed the function F is homogenous of degree1 in all its inputs R_i, K_i, L_i and treats R_i as a rival good.

Romer took three key elements in his model: externalities, increasing returns in the production of output and diminishing returns in the production of new knowledge. It is the spillovers from research efforts by a firm that leads to the creation of new knowledge by other firms. New research technology by a firm spill over instantly across the entire economy. In this model, new knowledge is the ultimate determinant of long run growth which is determined by investment in research technology. Research technology exhibits diminishing returns which means that investments in research technology will not double knowledge. Also, the firm investing in research technology will not benefit exclusively from the increase in knowledge. Other firms also benefit from new knowledge due to inadequacy of patent protection. Hence, the production of goods from increased knowledge displays increasing returns and competitive equilibrium is consistent with increasing aggregate returns owing to externalities. Romer took investment in research technology as endogenous factor in terms of the acquisition of new knowledge by rational profit maximizing firms.

6.3.5 The Lucas Model

Robert Lucas utilized a model of endogenous growth developed by Uzawa. Uzawa developed an endogenous growth model based on investment in human capital. Lucas assumed that investment on education leads to the production of human capital which is the crucial determinant in the growth process. He classified this as: internal effects of human capital where the individual worker undergoing training becomes more productive and external effects which spillover and increases the productivity of capital and of other workers in the economy.it is the investment in human capital rather than physical capital that have spillover effects that increase the level of technology.

Thus, the output for firm i takes the form

$$Y_i = A(K_i).\ (H_i)H^e$$

Where A is the technical coefficient

K_i and H_i are the inputs of physical and human capital used by firm i to produce output Y_i

H is the economy's average level of human capital and e is the parameter that represents strength of the external effects from human capital to each firm's productivity

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

6.3.6 Romer's Model of Technological Change

In 1990, Romer gave the model of endogenous technological change that identified a research sector specializing in the production of ideas. This sector invokes human capital along with the existing stock of knowledge to produce ideas or new knowledge. The importance of ideas over resources is the cornerstone of his analysis where he quotes Japan as an example, a country with few natural resources but open to new western ideas and technology.

In this model, new knowledge enters into the production process in three ways-

a) A new design is used in the intermediate goods sector for the production of a new intermediate input

b) In the final sector; labour, human capital and available producer durables produce the final product

c) A new design increases the total stock of knowledge which increases the productivity of human capital employed in the research sector.

The model is based on the following assumptions:

- Economic growth comes from technological change
- Technological change is endogenous
- Market incentives play an important role in making technological changes available in the economy
- Invention of a new design requires a specified amount of human capital
- The aggregate supply of human capital is fixed
- Knowledge or a new design is assumed to be partially excludable and retainable by the firm who invented it (patented design that cannot be made or sold without the agreement of the inventor) but investment in R&D can be done by other firms and benefits can be accrued thereof.
- Technology is a non-rival input.

- The new design can be used by firms and in different periods without additional costs and without reducing the value of the input.
- The low cost of using an existing design reduces the cost of creating new designs.
- When firms make investments in R&D and invent a new design, there are externalities that are internalized by private agreements.

Technological production function in the model is given by

$$\Delta A=F (K_A, H_A, A)$$

Where ΔA is the technology production function for technology (Δ stands for change in value; thus ΔA stands for change in technology)

K_A is the amount of capital invested in producing the new design or technology

H_A is the amount of human capital (labour) employed in R&D of the new design

A is the existing technology of designs.

The production function shows that technology is endogenous. When more human capital is employed for R&D of new designs, then technology increases by a larger amount that is A is greater. Since it is assumed that technology is a non-rival input and partially excludable, there are positive spillover effects of technology which can be used by other firms. Thus, the production of new technology (knowledge or ideas) can be increased through the use of physical capital, human capital and existing technology.

Check Your Progress 2

1. Explain the learning by doing model by Kenneth Arrow?

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2. Examine the relevance of Paul Romer's model of technological change in explaining long run growth across countries.

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6.4 CRITICISM OF ENDOGENOUS GROWTH MODELS

Many economists have criticized the new growth theory on their respective considerations, some based on the general suggestion that endogenous growth theory is not novel, such as

- Scott and Auerbach think that the main ideas of the new growth theory can be traced to Adam Smith and increasing returns of Marx's analysis.
- Srinivasan does not find anything new in the new growth theory as increasing returns and endogeneity of variables have been taken from neoclassical and Kaldor models of growth.
- Fisher criticizes it for depending only on the production function and steady state.
- Olson feels that it lays too much emphasis on the role of human capital and neglects the role of institutions.
- In various models of new growth theories, the difference between physical and human capital is not clear.

However, a few general limitations can also be highlighted,

- Endogenous growth theory is impossible to be validated through empirical evidence.
- It is accused of being based on assumptions that cannot be accurately measured.
- These theories have collectively failed to explain conditional convergence reported in empirical evidence.
- An important shortcoming of the new growth theory is that it remains dependent on a number of assumptions of the traditional neoclassical theory that are often inappropriate for developing and underdeveloped economies.
- In developing countries, economic growth is frequently impeded by inefficiencies due to poor infrastructure, inadequate institutions and imperfect capital and goods markets. The endogenous growth theory fails to incorporate these factors.
- The theory particularly looks at long run growth and ignores short- and medium-term growth.

6.5 POLICY IMPLICATIONS FOR DEVELOPED AND DEVELOPING COUNTRIES

- This theory suggests the convergence of growth rates per capita of developing and developed countries can no longer be expected to occur. The increasing returns to both physical and human capital imply that the rate of return to investment will not fall in developed countries relative to developing countries. Therefore, capital need not flow from developed to developing countries and actually the reverse may happen.
- The measured contribution of both physical and human capital to growth may be larger than suggested by the Solow Model. Investment in education or R&D has not only a positive effect on the firm itself but also spillover effects on the other firms and economy as a whole. This suggests that the residual attributed to technological change in the Solow growth accounting may be actually smaller. Recent growth accounting

exercises have suggested that the percentage of growth accounted for by the 'unexplained residual', is much smaller for the less advanced economy. This may of course simply reflect capital in these countries. Alternatively, it may reflect other considerations generally excluded from growth theory but which possess particular relevance for the developing economies. Stern (1991) for example, has stressed the importance of management, organization, infrastructure, and sectoral transfer as key elements in the growth process of third world economies

- It is not necessary that economies having increasing returns to scale must reach steady state level of income growth as suggested by Solow-Swan Model. With positive externalities of Research and Development, growth of income does not slow down and economy does not reach steady state. An increase in savings rate can lead to a permanent increase in the growth rate of the economy.
- Countries having greater stocks of human capital and investing more in R&D will enjoy a faster rate of economic growth. This may be the reason for slow growth of many developing countries.
- Potentially, it is the less developed economy which stands to gain the most from international trade becoming freer since by doing so it can draw upon the stock of world knowledge. But technological flows from rich to poor economies are by no means automatic which raises the issue of the role of multinational corporations and how they respond to incentives for technological transfer. This leads naturally into the question of policy. The essence of modern statements of endogenous growth is that the technical progress residual is accounted for by endogenous human capital formation. But if the latter can be influenced by government policy world growth may be changed accordingly. For example, if a country possessed of a comparative advantage in R & D activity were to subsidize research, world growth would increase. In the same way, a similar subsidy introduced by an economy relatively more efficient in manufacturing as opposed to innovating may cause world growth to decline. Trade policies which afford protection to the manufacturing sector may promote the transfer of skilled labour from research activity into manufacturing which will retard innovation. Ceteris paribus, trade policy will affect a shift of resources from research to manufacturing in policy active countries and in the opposite direction in policy inactive countries.
- Implications also emerge for the international product cycle. Traditionally, invention and new products occur in the advanced economy where R& D activity is well developed. Later, either by imitation or technology transfer they will be produced in the less advanced country and ultimately production of these goods will migrate to the low wage economy. Accordingly, trade in manufactured products takes place on the basis of exchange between the latest innovative goods produced only in the advanced economy and the more traditional goods now produced

predominantly by the less advanced. The product cycle accounts for an ever-evolving pattern of international trade with the advanced economy importing the very same goods that initially it exported. In the context of the product cycle model, international trade always emerges as a contributor to faster economic growth in both advanced and less advanced economies. In the former, the migration of production from the advanced to the less advanced economy frees resources for use in growth enhancing product development activity. At the same time, growth occurs faster in the less advanced economy since the resources needed for learning and adapting the techniques imported from the advanced economy are far fewer than those needed for autonomous new product development. In both cases, the subsidization of learning activities (innovation in the advanced economy, imitation in the less advanced) may be expected to enhance long run growth rates.

- Finally, it would appear clear that trade policy has the potential for influencing long run growth paths for the world economy. However, numerous difficulties present themselves. The identification of growth influencing knowledge sectors is itself a major difficulty ex ante if not ex post. Secondly, the fact that conclusions deriving from the model analysis can be so easily overturned by the alteration of the conditions or assumptions underlying the analysis - which for the most part are unlikely to be resolved empirically - weakens one's confidence in growth prescription. Moreover, in the context of international trade and the world economy, the outcome and effects of policy measures are themselves interdependent with the policy actions of others. This would point to the need for the coordination of national policies or at least the consideration of second-best outcomes.

An endogenous growth theory implication is that policies that embrace openness, competition, change and innovation will promote growth. Conversely, policies that have the effect of restricting or slowing change by protecting or favouring particular existing industries or firms are likely, over time, to slow growth to the disadvantage of the community.

Check Your Progress 3

1. What are criticisms of endogenous growth theory?

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2. Discuss the policy implications of endogenous growth for developing and developed countries

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6.6 LET US SUM UP

Endogenous growth is long-run economic growth at a rate determined by forces that are internal to the economic system, particularly those forces governing the opportunities and incentives to create technological knowledge. In the long run the rate of economic growth, as measured by the growth rate of output per person, depends on the growth rate of total factor productivity (TFP), which is determined in turn by the rate of technological progress. The neoclassical theory implies that economists can take the long-run growth rate as given exogenously from outside the economic system. Endogenous growth theory challenges this neoclassical view by proposing channels through which the rate of technological progress, and hence the long-run rate of economic growth, can be influenced by economic factors. It starts from the observation that technological progress takes place through innovations, in the form of new products, processes and markets, many of which are the result of economic activities. For example, because firms learn from experience how to produce more efficiently, a higher pace of economic activity can raise the pace of process innovation by giving firms more production experience. Also, because many innovations result from R&D expenditures undertaken by profit-seeking firms, economic policies with respect to trade, competition, education, taxes and intellectual property can influence the rate of innovation by affecting the private costs and benefits of doing R&D.

The central tenets of endogenous growth theory and policy implications thereof include:

- Government policy's ability to raise a country's growth rate if they lead to more internal competition in markets and help to stimulate product and process innovation.
- There are increasing returns to scale from capital investment especially in infrastructure and investment in education, health and communications.
- Private sector investment in R&D is a crucial source of technological progress.
- The protection of property rights and patents is essential in providing incentives for businesses and entrepreneurship to engage in R&D.
- Investment in Human capital is a vital component of growth.

- Government policy should encourage entrepreneurship as a means of creating new businesses and ultimately as an important source of new jobs, investment and further innovation.

6.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1. See section 6.1

2. See section 6.2

Check Your Progress 2

1. See sub-section 6.3.1

2. See sub-section 6.3.6

Check Your Progress 3

1. See section 6.4

2. See section 6.5