



THEORY OF ECONOMICS GROWTH

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SYLLABUS
THEORY OF ECONOMICS GROWTH

Objectives :

The purpose of this course is to introduce students to issues and problems related to economic development. Specifically, we will discuss the characteristics of developing nations as well as alternative theories of economic growth. Student will examine some of the dominant domestic problems faced by developing countries, such as, low levels of human capital, urbanization, rural transformation as well as different policies to resolve them.

Sr. No.	Description
1	Economics of Growth and Development: Meaning, Measurement, Difference and Comparisons. Sources of Economic Growth. Human Development Index and PQLI
2	Economic Growth Models-I: Harrod-Domar Growth Model, Neo-Classical Growth Models
3	Economic Growth Models-II: Growth and Distribution, Total Factor Productivity and Growth Accounting, Technological Change and Progress
4	Economic Growth Models – III : Model of Optimal Economic Growth, Multi-Sector Models of Growth,
5	Endogenous Growth Models, Stochastic Growth Models- Business Cycle Theory

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Unit 1 : Economics of Growth and Development: Meaning, Measurement, Difference and Comparisons

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- 1.9 Factors Affecting Economic Growth
- 1.10 Summary
- 1.11 Key-words
- 1.12 Review Questions
- 1.13 Further Readings

Objectives

After reading this unit students will be able to:

- Describe the economic development and economic growth.
- Explain the economic growth and development : A contrast.
- Understand the growth performance of the world economy.
- Know about the study the process of economic growth.
- Learn the measurement of growth.

Introduction

In recent years, there has come into existence a new branch of economics known as the “Economics of Development”. It refers to the problems of the economic development of underdeveloped or backward countries. In addition to the illuminating reports of the U.N.O. on the subject, some top ranking economists like Nurkse, Dobb, Staley, Buchanan, Rostow and Ellis have made some original contributions to the Economics of Development. The main reason for the growing popularity of “Economics of Development” as a separate branch of economic theory is the increasing tendency on the part of the newly independent countries of Asia and Africa to resort to developmental planning as a means to eliminate their age-old poverty and raise living standards.

1.1 Meaning of Economic Development

Economic development is a process whereby an economy's real national income as well as per capita income increases over a long period of time. Here, the process implies the impact of certain forces which operate over a long period and embody changes in dynamic elements. It contains changes in resource supplies, in the rate of capital formation, in demographic composition, in technology, skills and efficiency, in institutional and organisational set-up. It also implies respective changes in the structure of demand for goods, in the level and pattern of income distribution, in size and composition of population, in consumption habits and living standards, and in the pattern of social relationships and religious dogmas, ideas and institutions. In short, economic development is a process consisting of a long chain of inter-related changes in fundamental factors of supply and in the structure of demand, leading to a rise in the net national product of a country in the long run.

1.2 Definitions of Economic Development

The term 'economic development' is generally used in many other synonymous terms such as economic growth, economic welfare, secular change, social justice and economic progress. As such, it is not easy to give any precise and clear definition of economic development. But in view of its scientific study and its popularity, a working definition of the term seems to be quite essential. Economic development, as it is now generally understood, includes the development of agriculture, industry, trade, transport, means of irrigation, power resources, etc. It, thus, indicates a process of development. The sectoral improvement is the part of the process of development which refers to the economic development. Broadly speaking, economic development has been defined in different ways and as such it is difficult to locate any single definition which may be regarded entirely satisfactory.

1.3 Characteristics of an Developed Economy

A developed economy is the characterised by increase in capital resources, improvement in efficiency of labour, better organisation of production in all spheres, development of means of transport and communication, growth of banks and other financial institutions, urbanisation and a rise in the level of living, improvement in the standards of education and expectation of life, greater leisure and more recreation facilities and the widening of the mental horizon of the people, and so on. In short, economic development must break the poverty barrier or the vicious circle and bring into being a self-generating economy so that economic growth becomes self-sustained.

The main characteristics of developed countries are as follows:

1. Significance of Industrial Sector.
2. High Rate of Capital Formation.
3. Use of High Production Techniques and Skills.
4. Low Growth of Population.

These are discussed in below.

1. Significance of Industrial Sector: Most of the developed countries in the world have given much importance of the development of industrial sector. They have large capacities to utilise all resources of production, to maximise national income and to provide employment for the jobless people. As we are quite aware that these countries receive the major portion of their national income from the non-agriculture sectors which include industry, trade, transport, and communication. For instance, England generally receives nearly 50% of her national income from industrial sector, 21% from transport and commerce, 4% from agriculture and 25% from other sectors. The same case is with the U.S.A., Japan and other West European countries. But in India and other developing countries agriculture contributes, say, 35 to 40 percent, to their national income.

2. High Rate of Capital Formation: Developed countries are generally very rich, as they maintain a high level of savings and investment, with the result that they have huge amount of capital stocks.

The rate of investment constitutes 20 to 25 percent of the total national income. The rate of capital formation in these countries is also very high.

Besides this, well-developed capital market, high level of savings, broader business prospects and capable entrepreneurship have led to a high growth of capital formation in these economies.

3. Use of High Production Techniques and Skills: High production techniques and skills have become an essential part of economic development process in the developed countries. The new techniques have been used for the exploitation of the physical human resources. These countries have, therefore, been giving priority to the scientific research, so as to improve and evolve the new and technique of production. Consequently, these countries find themselves able to produce goods and services of a better equality comparatively at the lesser cost. It is because of the use of high production techniques and latest skills, that the countries like Japan, Germany and Israel could have developed their economies very rapidly, though they have limited natural resources.

4. Low Growth of Population: The developed countries, like the U.S.A., the U.K. and other Western European countries have low growth of population because they have low level of birth rate followed by low level of death rate. Good health conditions, high degree of education and high level of consumption of the people have led to maintain low growth of population followed by low level of birth and death rates. The life expectancy in these countries is also very high. The high rate of capital formation on the one hand and low growth of population have resulted in high level of per capita income and prosperity in these countries. Consequently, the people in these countries enjoy a higher standard of living and work together unitedly for more rapid economic and industrial development of the nations. Besides this, the entire society, its structure and values are found to be dedicated to the goal of rapid economic and industrial development. The position of individuals in the society is decided by the ability of the persons and not by their birth, caste or creed. Dignity of labour is maintained. The economic motive and strong desire to lead a better social life always inspire people to contribute to the process of development. The main objective of rapid economic development, particularly in the developed economies is to achieve the level of stagnant economic growth, so that they may maintain the existing economic status and exercise control over business cycle.

1.4 Distinction Between Developed and Underdeveloped Economies

We may now distinguish between the features of an underdeveloped economy from that of developed one as follows:

1. Underdeveloped economies are distinguished from developed economies on the basis of per capita income. In general, those countries which have real per capita incomes less than a quarter of the per capita income of the United States, or roughly less than 5000 dollars per year, are categorized as under-developed countries.
2. An underdeveloped economy, compared with an advanced economy, is underequipped with capital in relation to its population and natural resources. The rate of growth of employment and investment in such an economy lags behind the rate of growth of population. The resources are not only employed but also underemployed. In technical jargon, the production possibility frontier of a poor country is far ahead of the actual production curve, whereas the gap between the potentiality and actual utilisation of resources is narrow in a developed economy.
3. High rate of growth of population is an important characteristic of most of the underdeveloped economies. Population growth in underdeveloped countries neutralises economic growth. In advanced economies, the case is different. As Prof. Hansen points out, one of the empirical tests of secular stagnation in advanced economies is the declining rate of population growth. The stagnation problem in a developed economy is a problem of population, natural resources and technology failing to keep pace with capital accumulation.
4. The central problem of underdeveloped economies is the prevalence of mass poverty which is the cause as well as the consequence of their low level of development. Shortage and scarcity are the main economic problems in these economies, whereas the affluent societies of advanced countries have economic problems resulting from abundance.

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5. In an underdeveloped economy, the fundamental problem is that of output, real income or the standard of living, as these economies are characterised by low productivity, low income and a poor standard of living. A vast majority of people in an underdeveloped country are ill-clothed, undernourished and without adequate shelter. To use Rostow's terminology, economies of poor countries similar to those of a traditional society, where modern science and technology are either not available or not regularly and systematically applied. On the other hand, most of the developed countries at present enjoy a high rate of mass-consumption. In their economies, per capita real income has risen to a level at which a large number of people can afford consumption transcending food, shelter and clothing.
6. Capital deficiency is the main cause of poverty of a poor country, while affluent capital accumulation is the main cause of stagnation of an advanced country.
7. In an underdeveloped economy, the problem of under-employment is more important than that of unemployment, whereas a developed economy may have a cyclical unemployment problem. There is chronic unemployment in an underdeveloped economy. An advanced economy may have unemployment occasionally due to business fluctuations and a low marginal propensity to consume. Whereas an under developed economy is confronted with the problem of disguised unemployment in the sense that even with unchanged techniques in agriculture could be removed without reducing agricultural output. Thus, in a developed economy, unemployment means waste of resources, while in an underdeveloped economy, it is of disguised type.
8. Poor countries are poor in technology, advanced countries are advanced in technology. In fact, the level of technology attained in production is a reliable indication of the level of economic development. Employment of advanced technology goes along with large capital resources, high attainments in the fields of scientific research, greater availability of entrepreneurial skill and a good supply of efficient skilled labour. Thus, development of technology is the basic objective of the backward economy whereas development of technology no longer remains the overriding objective of an affluent society.



Notes

Economic growth is a necessary but not sufficient condition of economic development.

Self-Assessment

1. Fill in the blanks:
 - (i) a way of life.
 - (ii) Economic growth is a narrower concept than development
 - (iii) Economic development is a concept.
 - (iv) Economic growth does not take into account the size of the economy.
 - (v) Economic growth is but not sufficient condition of economic development.

1.5 Difference between Economic Growth and Economic Development

The difference between economic growth and economic development are:

1. Economic Growth is quantitative while economic development is qualitative.
2. Economic growth is comparatively a narrow concept and development is much more comprehensive.
3. Economic growth refers to increase in the total output of final goods and services in a country over a long period of time. In contrast, economic development refers to progressive change in the socio-economic structure of the country. It includes gender equality, change in composition of output, shift of labour force from agriculture to other sectors.

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4. Economic growth is easy to realize as only monetary aspect is involved. But, it is very difficult to attain the goal of development as it involves many socio-economic-political aspects.
5. Economic growth can easily be estimated by real GDP or Real Per Capital income. But it is very difficult to measure development as it has some aspects that can't be quantified. Economic development however is indicated by Human Development Index.
6. Economic growth can take place without Economic development; however, economic development can't take place without economic growth.

The difference between extensive and intensive growth can be summarized as below :

1. Extensive growth refers to growth in total output level of an economy. Intensive growth refers to increase in per capita level of the output.
2. If output takes a jump due to unexpected one time force, it is called extensive growth. If there is continuous expansion in output due to some positive change over time, it is called intensive growth.
3. Extensive growth is temporary and short lived. However intensive growth is permanent and has long lasting effects.
4. Extensive growth is relevant to study aggregative phenomenon such as economies of scale. Intensive growth is relevant to study the increase in standard of living of the people of a country.



Did u know? There is no doubt that the performance of Indian economy has improved a lot and is superior to many other countries of the world.

1.6 Comparison of Economic Growth and Economic Development

Economic	Development	Economic Growth
Concept:	Normative concept	Narrowed concept than economic development
Scope:	Concerned with structural changes in the economy	Growth is concerned with increases in the economy's output
Growth:	Development relates to growth of human capital indexes, a decrease in inequality figures, and structural changes that improve the general population's quality of life	Growth relates to a gradual increase in one of the components of Gross Domestic Product: consumption, government spending, investment, net exports
Implication:	It implies changes in income, saving and investment along with progressive changes in socio-economic structure of country (institutional and technological changes)	It refers to an increase in the real output of goods and services in the country like increase the income in savings, in investment etc.
Measurement:	Qualitative. HDI (Human Development Index), gender-related index (GDI), Human poverty index (HPI), infant mortality, literacy rate etc.	Quantitative Increase in real GDP. Shown in PPF.
Effect:	Brings qualitative and quantitative changes in the economy	Brings quantitative changes the economy

1.7 Economic Development and Economic Growth

By a “developed” economy, people roughly mean ones with a high, persistently-growing per-capita income which is not simply based on resource extraction (i.e., oil) or remittances or rentierism – an industrial (or, if there is such a thing, post-industrial) economy which makes most of its participants reasonably and increasingly prosperous. While there are of course differences among them – the United States is not New Zealand, which is not Belgium, which is not Finland, which is not Japan – they are all more similar to each other than they are to the vast variety of “undeveloped”, “under-developed”, or (most optimistically) “developing” economies across the world. (Some people refer to the developed countries as “the North” and the others as “the South”; this drives me up the wall, if only from looking at where China and Australia are on the map.) Economies in the first category tend to stay there; so, sadly, do countries in the second. Development economics is the sub-discipline of economics which attempts to study how economies which have not attained this happy condition can be made to do so, and the factors which hold others back.

Normally in economic textbooks, growth and development are used synonymously, and this usage is widely acceptable. However, in particular, the two terms have been distinguished by different economists as follows:

1. To some economists, economic development refers to the process of expansion of backward economies, while economic growth relates to that of advanced economies.
2. **Schumpeter**, however, uses the term “economic development” as a spontaneous and discontinuous change in the stationary state which disturbs the equilibrium state previously existing. And the term “economic growth” is used to denote a steady and gradual change in the long run which comes through a general increase in the rate of saving and population in a dynamic economy.
3. **Prof. Kindleberger** has given the differences between growth and development as; “Growth may well imply not only more output and also more inputs and more efficiency, i.e., an increase in output per unit of input. Development goes beyond these to imply changes in the structure of outputs and in the allocation of inputs by sectors. By analogy with human beings to stress growth involves focusing on height and weight, while to emphasize development, draws attention to the change in functional capacity in physical coordination. For example, growth without development—more and more steel in the Soviet Union or more and more coffee in Brazil—leads nowhere. It is virtually impossible to contemplate development without growth because change in function requires a change in size. Until an economy can produce a margin above its food, through growth, it will be unable to allocate a portion of its resources to other types of activity”.
4. To some, economic development is the outcome of conscious and deliberate efforts involved in planning. Economic growth, on the other hand, signifies the progress of an economy under the stimulus of certain favourable circumstances, e.g., the progress achieved by the United Kingdom during the Industrial Revolution.
5. In his simple words, **A. Maddison** says, “The raising of income levels is generally called economic growth in rich countries and in poor ones it is called economic development”. **Mrs. Hicks** has also expressed almost the same views and said that economic development refers to the problems of underdeveloped countries and economic growth to those of advanced countries she points out that the problems of underdeveloped countries are concerned with development of unused resources, even though their uses are well-known; while those of advanced countries are related to growth, most of their resources being already known and developed to a considerable extent.
6. According to **Prof. Mehta**, however, the term “growth” has quantitative significance. Growth suggests an increase in the quantity or volume of something. An increase in a country’s population, national income; per capita income, consumption, saving, investment, foreign

trade etc. over a period, all imply growth. In economics, however, growth strictly means an increase in real income, gross and per capita. On the other hand, development is a process of expansion, fulfilling the desire to have an increase in national income. From the above will be clear, the distinction and interface of growth and development.



Caution It also occurs by increasing the productivity of existing factors through investment in education (labour) and technology (capital).

1.8 Measuring of Growth and Production Possibilities

Economic growth is the increase in the amount of the goods and services produced by an economy over time. It is conventionally measured as the percent rate of increase in real gross domestic product, or real GDP. Growth is usually calculated in real terms, i.e. inflation-adjusted terms, in order to obviate the distorting effect of inflation on the price of the goods produced. In economics, “economic growth” or “economic growth theory” typically refers to growth of potential output, i.e., production at “full employment”.

As an area of study, economic growth is generally distinguished from development economics. The former is primarily the study of how countries can advance their economies. The latter is the study of the economic aspects of the development process in low-income countries. See also Economic development.

Since economic growth is measured as the annual percent change of gross domestic product (GDP), it has all the advantages and drawbacks of that measure.

1.8.1 Economic Growth: Measurement

Economic growth is the sustained increase in welfare of an economy nation, region, city together with the ongoing changes in that economy’s industrial structure; public health, literacy, and demography; and distribution of income. In the long run, as this economic transformation evolves, so do social, political, and cultural norms. Societies change profoundly and multi-dimensionally, as economic performance improves.

To measure economic growth is to quantify this increase in welfare and to endow with numerical precision these large-scale economic and social changes. Given the breadth of possibilities, it is impossible to undertake this measurement exercise without guidance of what can be pared away, what is essential from some view on the causes of growth (see, e.g., Economic Growth: Theory).

This article sets down some key (measurement) facts concerning economic growth, and documents how they have evolved, if at all, over time. In doing this, the article attempts also to illustrate the historical interplay between two lines of research, measurement of and theories about economic growth, each influencing the other.

1. National Income: The panorama above of profound social and economic changes can be simplified dramatically by concentrating on just a single key economic variable, income per capita. (We will return in Sect. 8 below to issues of broader structural transformations). Income per capita is the per head measure of the total value of all goods and services produced in an economy. Taking national income measured by either gross national product (GNP) or gross domestic product (GDP), or its regional counterpart and dividing it by population in the appropriate nation or region gives a convenient first measure on the state of economic well-being. Since total income is the same as total output, this measure might sometimes be usefully replaced by output per worker, or labor productivity, where the denominator is then the size of the labor force; or, even output per worker-hour, where the measure then takes into account the time spent working by the labor force. In some detailed analyses, these alternatives can provide different useful insights into economic performance different countries, at different times, have had their labor force markedly different from their population, or have had workers and make different choices on the length of their workday.

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However, for the kind of long-horizon, large-scale developments that are typically of interest in economic growth, these differences are inessential. Potentially more important is whether this one measure can suitably proxy for the wide spectrum of different variables of concern in economic growth. Across countries, per capita income is positively correlated with a broad range of alternative indicators for economic performance including life expectancy, (the negative of) infant mortality, and adult literacy.

1.9 Factors Affecting Economic Growth

The process of economic growth is a highly complex phenomenon and is influenced by numerous and varied factors such as political, social and cultural factors. As such economic analysis can provide only a partial explanation of this process. To repeat here the remark of Prof. Ragnar Nurkse in this connection, "Economic development has much to do with human endowments, social attitudes, political conditions and historical accidents. Capital is a necessary but not a sufficient condition of progress". The supply of natural resources, the growth of scientific and technological knowledge—all these too have a strong bearing on the process of economic growth. We shall briefly notice some of these factors one by one.

1.9.1 Economic Factors

The following are the important factors which determine the economic growth of an economy.

1. **Natural Resources:** The principal factor affecting the development of an economy is the natural resources. Among the natural resources, we generally include the land area and the quality of the soil, forest wealth, good river system, minerals and oil resources, good and bracing climate, etc. For economic growth, the existence of natural resources in abundance is essential. A country deficient in natural resources may not be in a position to develop rapidly. In fact natural resources are a necessary condition for economic growth but not a sufficient one. Japan and India are the two contradictory examples. As pointed out by Lewis, "other things being equal man can make better use of rich resources than they can of poor". In less developed countries, natural resources are unutilised, underutilized or misutilised. This is one of the reasons of their backwardness. There is little reason to expect natural resource development if people are indifferent to the products or service which such resources can contribute. This is due to economic backwardness and lack of technological factors. According to Professor Lewis, "A country which is considered to be poor in resources may be considered very rich in resources some later time, not merely because unknown resources are discovered, but equally because new methods are discovered for the known resources". Japan is one such country which is deficient in natural resources but it is one of the advanced countries of the world because it has been able to discover new use for limited resources.
2. **Capital Formation:** Among several economic factors, capital formation is another important factor for development of an economy. Capital may be defined as the stock of physical reproducible factors of production. Capital accumulation and capital formation, both of these terms carry the same meaning which may be understood simply by the stock of capital. As we know, capital formation is cumulative and self-feeding and includes three interrelated stages; a) the existence of real savings and rise in them; b) the existence of credit and financial institutions to mobilise savings and to divert them in desired channels; and c) to use these savings for investment in capital goods.

Low propensity to save in underdeveloped countries is due to low per capita income of the people, which may not be raised merely by voluntary savings. Hence, the rate of per capita savings can be increased by emphasizing forced savings which will reduce consumption and thereby release savings for capital formation. Forced savings can be possible through the implementation of a proper fiscal policy. In this regard, taxation, deficit financing and public borrowing are better instruments in the hands of the State to collect savings and accumulate

capital. Nurkse's suggestion to use unemployed or underemployed rural youths in construction works has importance for capital formation in backward economies. In addition to it, the external resources like foreign loans and grants, and larger exports can also help these economies in capital formation.

The capital formation possesses special significance, as it is key to economic growth, particularly in backward economies. It increases sectoral productivity in the economy on the one hand and enhances ultimately national output by raising effective demand, on the other. According to Kuznets' estimates, during modern economic growth the gross capital formation and net capital formation was gradually between 11.13 to 20 percent and 6 to 12.14 percent in developed countries. According to Lewis, the rate in underdeveloped countries was 5 percent or less which should be raised to the level of 12 to 15 percent.

- 3. Technological Progress:** The technological changes are most essential in the process of economic growth. Adam Smith, the father of political economy, pointed out the great importance of technological progress in economic development. Ricardo visualised the development of capitalist economies as a race between technological progress and growth of population. The great importance of technological progress in capitalist development was recognised by Karl Marx too.

There is no doubt that technological progress is a very important factor in determining the rate of economic growth. In fact, even capital accumulation is not possible without technical progress. A country may be adding to its means of transportation and communications, its power resources and its factories.

According to modern technique, it is called widening of capital. The use of improved techniques in production and technological progress bring about a significant increase in per capita income. Technological progress has something to do with the research into the use of new and better methods of production or the improvement of the old methods. Sometimes technical progress results in the availability of natural resources. But generally technological progress results in increase in productivity, e.g., green revolution. In other words, technological progress increases the ability to make a more effective and fruitful use of natural and other resources for increasing production. By the use of improved technology it is possible to have greater output from the use of given resources or a given output can be obtained by the use of a smaller quantity of resources.

It is a matter of common knowledge that technological progress adds greatly to our ability to make a fuller use of the natural resources, e.g., generation of hydro-electricity. With the aid of power - driven farm equipment a marked increase has been brought about in agricultural yields per acre and per worker.

Technical progress also increases the ability to make a more effective use of capital equipment. Technological progress has very close connection with capital formation. In fact, both go hand in hand. Without capital formation technical progress is out of the question because heavy investment is required for making use of better and more efficient methods of production, although after they are well established, capital cost per unit of output may fall.

Thus, technological progress has a very important role to play in the economic development of a country. No backward country can hope to march ahead on the road of economic development with out adopting a newer and newer techniques of production and unless it is assisted in its march by technological progress. We have already brought out the importance of capital accumulation in economic growth. But capital accumulation promotes economic growth because it facilitates technological improvements, which raise labour productivity and thus add to the national and percapita income.

- 4. Human Resources:** A good quality of population is very important in determining the rate of economic progress. Instead of a large population a small but high quality of human race in a

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country is better for development. Thus, for economic growth, investment in human capital in the form of educational and medical and such other social schemes is very much desirable.

According to **Peter Drucker** : “The most important requirement of rapid industrial growth is people. People ready to welcome the challenge of economic change and opportunities in it. People, above all, who are dedicated to the economic development of their country, and to high standards of honesty, competency, knowledge and performance. What are needed beyond all else are leadership and example, and that, only the right kind of people can provide”. Prof. Drucker stressing the significance of human capital says further : “Capital without people is sterile, but people can move mountains without capital. Development, therefore, requires rapid growth of human talents and opportunities to employ them”.

5. **Population Growth:** Labour supply comes from population growth. But the population growth should be normal. A galloping rise in population retards economic progress. Population growth is desirable only in a under-populated country. It is, however, unwarranted in an overpopulated country like India. In fact, a high population growth at the rate of 2.5 percent per annum is very much detrimental to the economic growth of our country.
6. **Social Overheads:** Another important determinant of economic growth is the provision of social overheads like schools, colleges, technical institutions, medical colleges, hospitals and public health facilities. Such facilities make the working population healthy, efficient and responsible. Such people can well take their country economically forward.
7. **Organisation:** In the process of growth, organisation is very important. It is organization that emphasises maximum use of the means of production in production. Organisation is complementary to capital and labour and helps production to reach the maximum level. In the modern economic system, the entrepreneur performs the duty of an organiser and bears all risks and uncertainties. Hence, entrepreneurship is an indispensable part in the process of economic growth. For instance, the Industrial Revolution in England succeeded because of the entrepreneurship.

Most of the underdeveloped countries in the world are poor not because there is shortage of capital, weak infrastructure, unskilled labour and deficiency of natural resources, but because of acute deficiency of entrepreneurship.

Myrdal rightly comments, “the Asian countries lack entrepreneurship not because they are deficient in capital or raw materials but because they are deficient in persons with right attitude for entrepreneurship”. Behind Japan’s rapid economic growth there is only one reason that it has entrepreneurship in abundance. It is, therefore, essential in LDCs to create climate for promoting entrepreneurship by emphasising education, new researches, and scientific and technological developments. Apart from it, the state should also give priority to necessary imports of machines, raw materials and equipments to provide facilities for wider markets, and to allow tax rebates, special grants and loans to the new entrepreneurs for starting business or industries particularly in the undeveloped areas of an economy.

8. **Transformation of Traditional Agricultural Society:** The transformation of traditional agricultural society into a modern industrial society, i.e., structural changes lead to enhancement of employment opportunities, higher labour productivity and the stock of capital, exploitation of the newly developed resources and improved technology. Mostly, LDCs have a very large primary sector and very small secondary and tertiary sectors. In such economies the structural changes involve the transfer of population from the primary sector to the secondary and then to tertiary sectors. Agriculture being the main occupation of the 70-80 percent population in the LDCs passes through several structural changes. The number of dependents on agriculture sector progressively reduce with the expansion of industrial or nonagricultural sector.

Similarly, the proportion of contribution of agriculture in the real national income also reduces gradually. But net output in agriculture sector progressively increases in absolute terms, as it is accompanied by a strong productivity movement, relating to the implementation of several

programmes like land reforms, expansion of banks, improved agricultural techniques and other farm implements, availability of better marketing facilities, means of power and irrigation, and so on. In LDCs the agriculture and industry become complementary to each other. The progressively increasing productivity in agriculture enhances the per capita real income of the people, engaged in agriculture sector. This, in turn, expands rural demand for consumer goods and agricultural inputs which stimulates the expansion of industrial sector, and further, it also develops agriculture sector by providing improved farm techniques along with machines, fertilisers and other inputs. The scope for increasing agricultural productivity and incomes, in other words, is heavily dependent upon the structural transformation of the economy as it affects the growth of commercial demand for goods produced, the growth of alternative employment opportunities, and the increased quantity of purchased inputs available to the agricultural sector".

1.9.2 Non-Economic Factors

Both of the economic or noneconomic factors do play an important role in the process of economic growth. In this regard, socio-economic, cultural, psychological and political factors are also equally significant as are economic factors in economic development of the LDCs Cairncross rightly observes:

"Development is not just a matter of having plenty of money, nor is it purely an economic phenomenon. It embraces all aspects of social behaviour; the establishment of law and order; scrupulousness in business dealings, including dealings with the revenue authorities; relationships between the family, literacy, familiarity with mechanical gadgets and so on". We discuss here some of the essential noneconomic factors which determine the economic growth of an economy.

1. **Political Factors:** Political stability and strong administration are essential and helpful in modern economic growth. It is because of political stability and strong administration that the countries like the U.K. the U.S.A., Germany, France and Japan have reached the level of highest economic growth in the world. But in most of the poor countries there is political instability and weak administration which have largely influenced their economic development programmes. It is, therefore, essential for their faster economic development to have a strong, efficient and incorrupt administration. In conclusion, we can say that a clean, just and strong administration can put an economy on the way to rapid economic development. Lewis rightly comments that "no country has made progress without positive stimulus from intelligent governments".
2. **Social and Psychological Factors:** Modern economic growth process has been largely influenced by social and psychological factors. Social factors include social attitudes, social values and social institutions which change with the expansion of education and transformation of culture from one society to the other. The Industrial Revolution of England and other Western European countries in the 18th century was largely influenced by the spirit of adventure and the expansion of education which led to new discoveries and inventions and consequently to the rise of the new entrepreneurs. Social attitudes, values and institutions changed. Joint family system was replaced by the new single family system which further led to the rapid economic development in these countries.

But the society in LDCs has been badly enveloped and guided by traditional customs, outdated ideology, values, and obsolete attitudes which have not been conducive to their economic development. Thus, there is need to change or modify these social and psychological factors for the rapid economic development in these countries. But it is not an easy task, and moreover, any rapid change may bring discontentment and resistance in the society, with the result that it may adversely affect the economic growth in the economies.

Only the selective social and psychological changes can lead to economic growth in LDCs. According to the UN Report on Economic Development of Underdeveloped Countries, it is hence impossible to speed up economic growth in these economies without painful adjustments.

Notes

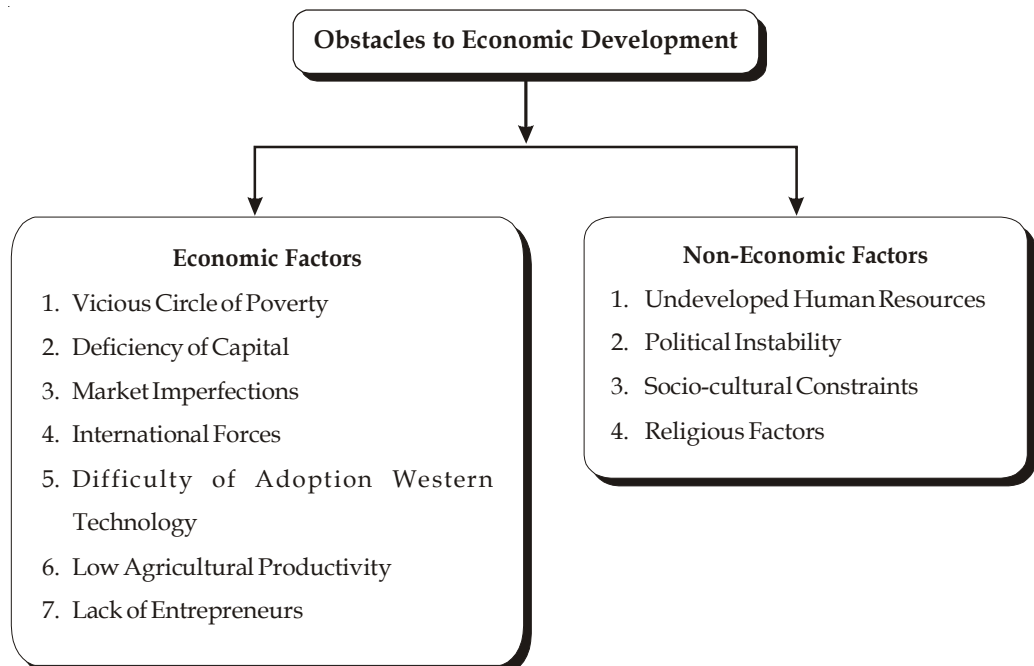
It, thus, advises to adopt an evolutionary change in social and cultural factors rather than revolutionary ones. **Myrdal** in his book **Asian Drama** also advocates the adoption of “modernisation values” or “modernisation ideals” for the rapid economic development of underdeveloped countries.

3. **Education:** It is now fairly recognised that education is the main vehicle of development. Greater progress has been achieved in those countries, where education is wide spread. J.K. Garlbraith in his book “Economic Development” has rightly stressed the role of education as an engine of economic growth.
4. **Urbanisation:** Another noneconomic factor promoting development is the process of urbanisation. In poor agrarian economies, the structural change must begin with the change in the size of population in rural and urban sectors.
5. **Religious Factors:** Religion plays a great role in economic growth. It may give rise to a peculiar sense of self-satisfaction. For example, the Hindu religion encourages faith in fate and prevents people from working hard. They are educated to remain satisfied with their lot and to hate risk and enterprise. Then our religion gives a higher place to spirit than matter.

In short economic growth is the result of concerted efforts of both economic and non economic factors. However, the mere presence of one or more or all of these factors may not ensure that the economy will be in a position to generate forces that bring about a fast economic growth. Some further factors may also be required that may work as a catalyst for growth. This function can well be performed by the state.

1.9.3 Obstacles to Economic Development

Broadly speaking, the features of an under developed economy create obstacles in the way of economic development, and hamper economic progress. These features emerge out of economic, social, political, religious and institutional factors. It would be wrong to conclude that only economic factors are responsible for poverty or economic backwardness of a country. Non-economic factors are equally responsible for the under development of an economy. The factors discouraging economic development may be classified into economic and noneconomic factors which are as under.





Task Write the growth theory.

Self-Assessment

2. State whether the following statements are 'true' or 'false'.
 - (i) The economic growth in different countries has been different and uneven.
 - (ii) If the growth rate is 10% it will only take 0.2 years for the economy to double.
 - (iii) A theory can help us to identify some strategic variables involved in the process of growth.

1.10 Summary

- Growth is a way of life. None of us wants to stay at the same level of standard of living. Each one of us puts best of his effort to grow economically and have a better standard of living.
- **Economic Growth** : is a narrower concept than economic development.
- **Economic development** is a normative concept i.e. it applies in the context of people's sense of morality (right and wrong, good and bad).
- The most accurate method of measuring development is the Human Development Index which takes into account the literacy rates & life expectancy which affect productivity and could lead to Economic Growth.
- Economic Growth does not take into account the size of the informal economy.
- Development alleviates people from low standards of living into proper employment with suitable shelter.
- If economic growth is 1%, it will take approximately 72 years for the value of the economy to double.
- If the growth rate is 10% it will only take 7.2 years for the economy to double.

1.11 Key-words

- Normative : Describing or setting standards or rules of behavior.
- Informal : Related and friendly not following strict rules of how to behave

1.12 Review Questions

1. What are difference between economic development and economic growth?
2. Explain the growth performance of the word economy.
3. Describe the process of economic growth.
4. What are the stages of growth?
5. Define growth also describe the measurement of growth.

Answer: Self-Assessment

1. (i) growth (ii) economic (iii) normative (iv) informal
(v) necessary
2. (i) T (ii) F (iii) T

Notes

1.13 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 2 : Sources of Economic Growth

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Objectives

Introduction

- 2.1 Sources of Economics Growth
- 2.2 Factors of source of Economic Growth
- 2.3 Summary
- 2.4 Key-words
- 2.5 Review Questions
- 2.6 Further Readings

Objectives

After reading this unit students will be able to:

- Explain about the sources of economic growth.
- Describe about the factors of source of economic growth.

Introduction

Economic growth is the continuous improvement in the capacity to satisfy the demand for goods and services, resulting from increased production scale, and improved productivity (innovations in products and processes). Factors improving productivity are particularly important sources of growth for developed economies with mature industries, but facing increasing global competition and rapid technological progress. Consumption has made a strong contribution to the growth of UK demand in recent decades, but the negative impact of the global financial crisis on consumer expenditure will persist for some time. Business investment is likely to become an increasingly important driver of growth. The UK's net trade position is expected to improve. Specialised and knowledge-intensive service and manufacturing sectors are likely to contribute strongly to future growth, building on the UK's relative specialization in Finance, Business Services, Communications, and Computer and Information Services.

2.1 Sources of Economic Growth

There are different concepts of economic growth and ways of measuring it, but the core definition is in terms of growth in the long run productive capacity of the economy, typically measured by real growth in Gross Domestic Product GDP.

Broader concepts of growth such as sustainable or balanced growth, or growth in measures of wellbeing are closer to welfare objectives but more complicated and harder to measure. Lets know the sources of economic growth.

2.1.1 Growth Accounting

Policy tends to focus on growth in output per capita, because it is more closely related to social welfare objectives. Growth in output per capita can be broken down into growth in the employment rate and in output per worker (a measure of productivity).

Notes

2.1.2 Drivers of Long Run Growth

There is a limit to how far the employment rate can be improved in the long term in developed countries, so long term growth is driven primarily by productivity. (*"Productivity isn't everything, but in the long run it is almost everything."* Paul Krugman). Over the longer term, growth will be determined primarily by the factors which determine productivity, and secondly those which improve labour participation.

The drivers of productivity growth are factors which either improve the quality of outputs, or the efficiency with which inputs (such as capital, labour and materials) are transformed into outputs. The contribution of some of these factors to output growth can be captured by appropriate input measures, with everything else (e.g. unmeasured inputs and technological progress) allocated to a residual called Total Factor Productivity (TFP).

2.1.3 Direct Inputs to Production

The main production inputs are capital, labour, management services and materials.

In the traditional Solow neoclassical growth model, a one-off increase in inputs to increase the scale of production only has an impact on per capita output growth in the short run, while technological progress (captured in TFP) makes a persistent contribution. However, in later endogenous growth models, investment (particularly in innovation) drives technological progress, so has an impact on growth in the long as well as short term.

2.1.4 Ancillary Firm Activities

Firms allocate resources to a range of activities (such as innovation, marketing, and specialisation) which do not form direct inputs into the production process, but ultimately affect the quality of outputs or the efficiency of input use.

Innovation by firms exploiting scientific advances creates the technological progress which is the main driver of growth in the long run.

Specialisation in products and processes (often involving greater trade) is an important route to increased productivity.

2.1.5 The Business Environment

There are a range of factors in the business environment (such as infrastructure, the efficiency of markets, market incentives, taxation and regulation) which affect the productivity of firms and the efficiency of the economy as a whole. Investment in infrastructure affects the costs to firms of accessing resources and markets, and market conditions affect firm incentives to invest, be enterprising and innovate.



Task

Which factors are responsible for economic growth?

2.2 Factors of Source of Economic Growth

Capital Formation: Capital is the foremost requirement for enhancing the productive capacity of the economy. The greater is the capital formation, greater will be the productivity of all other factors of production, and hence greater will be the total output of goods and services in the economy.

Empirical evidence also suggests that there is a strong positive correlation between the rate of capital formation and the rate of economic growth. Most of the developed countries of the world have high rates of capital formation.

Notes

Capital-Output Ratio: Another important factor determining the rate of economic growth is capital output ratio. It refers to the number of units of capital that are required in order to produce one unit of output.

There is a tendency that as an economy grows the capital output ratio becomes more and more favourable. Besides, capital output ratio also varies sector to sector and industry to industry.

To achieve high rate of economic growth of GDP, an economy has to ensure :

- (a) Increasing in the rate of capital formation;
- (b) Generating forces that increase the productivity of capital

Capital output ratio depends upon:

- (a) Efficiency in the use of capital;
- (b) Quality of managerial and organizational skill;
- (c) Marginal efficiency of capital.



Did u know? Rate of Growth of GDP = $\frac{\text{Investment - Income Ratio}}{\text{Capital - Output Ratio}}$

Occupational Structure: Occupational Structure refers to the distribution of work force over different sectors of an economy. There is an empirical evidence that as an economy grows there is a shift of labour force from primary to secondary and then to tertiary sector. This is called flight from land.



Notes With the shifting of labour from agriculture to service sector, efficiency of labour increases which in turn increases the efficiency of the economy.

Technological Progress: Technology can help to increase the productivity of existing resources. With improvement in technology, same resources become more productive. For example, Computer technology has increased the output of all kinds of offices many times. DMRC is another wonderful example for it. For technological advancement, we need to have quality of education and well equipped research and development.

Self-Assessment

1. Fill in the blanks:

- (i) in physical and human capital increases the productive capacity of the economy.
- (ii) helps to utilize the existing resources of the economy more efficiently.
- (iii) The greater is the capital formation, greater will be the of all other factors of production.
- (iv) Most of the developed countries of the world have high rates of
- (v) is the wonderful example of technology.

2.3 Summary

- Increases in productivity are the main factor responsible for economic growth, especially since the mid 19th century.
- The balance of growth has come from using more inputs overall because of the growth in output including new kinds of goods and services.

Notes

- Occupational Structure refers to the distribution of work force over different sectors of an economy.
- Investment in physical and human capital increases the productive capacity of the economy. Thereby, it helps to increase the total production of final goods and services in the economy over a long period of time. This is called economic growth.
- Technological progress helps to utilize the existing resources of the economy more efficiently.
- Capital is the foremost requirement for enhancing the productive capacity of the economy. The greater is the capital formation, greater will be the productivity of all other factors of production.

2.4 Key-words

- Occupational : Connected with a person's job or profession
- Structure : A thing that is made of several parts
- Technological : Scientific knowledge used in practical ways in industry

2.5 Review Questions

1. What are the sources of Economic Growth?
2. What are the factors of source of economic growth?
3. Give the formula to calculate rate of growth or GDP.

Answer: Self Assessment

1. (i) Investment (ii) Technological progress
(iii) productivity (iv) Capital formation (v) DMRC

2.6 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 3: Human Development Index and PQLI

Notes

CONTENTS

Objectives

Introduction

- 3.1 Human Development Index
- 3.2 New Method for 2011 Data onwards
- 3.3 Dimensions and Calculation
- 3.4 Future HDI Projections
- 3.5 Physical Quality of Life Index (PQLI)
- 3.6 Summary
- 3.7 Key-Words
- 3.8 Review Questions
- 3.9 Further Readings

Objectives

After reading this unit students will be able to:

- Define development Index.
- Know the method for 2001 data onwards.
- Explain the dimensions and calculation.
- Describe the physical quality and life income.

Introduction

The **Human Development Index (HDI)** is a composite statistic used to rank countries by level of “human development”, taken as a synonym of the older terms (the standard of living and/or quality of life), and distinguishing “very high human development”, “high human development”, “medium human development”, and “low human development” countries. HDI was devised and launched by Pakistani economist Mahbub ul Haq and Indian economist Amartya Sen in 1990. The HDI is a comparative measure of life expectancy, literacy, education, and standards of living of a country. It is a standard means of measuring well-being especially child welfare. It is also used to distinguish whether the country is a developed, a developing or an under-developed country, and also to measure the impact of economic policies on quality of life. There are also HDI for states, cities, villages, etc. by local organizations or companies.

3.1 Human Development Index

The origins of the HDI are found in the annual Human Development Reports of the United Nations Development Programme (UNDP). These were devised and launched by Pakistani economist Mahbub ul Haq in 1990 and had the explicit purpose “to shift the focus of development economics from national income accounting to people centered policies”. To produce the Human Development Reports, Mahbub ul Haq brought together a group of well-known development economists including: Paul Streeten, Frances Stewart, Gustav Ranis, Keith Griffin, Sudhir Anand and Meghnad Desai. But it was Nobel laureate Amartya Sen’s work on capabilities and functionings that provided the underlying conceptual framework. Haq was sure that a simple composite measure of human

Notes

development was needed in order to convince the public, academics, and policy-makers that they can and should evaluate development not only by economic advances but also improvements in human well-being. Sen initially opposed this idea, but he went on to help Haq develop the Index.

*Notes*

Sen was worried that it was difficult to capture the full complexity of human capabilities in a single index but Haq persuaded him that only a single number would shift the attention of policy-makers from concentration on economic to human well-being.

3.2 New Method for 2011 Data Onwards

In its 2010 Human Development Reports, the UNDP began using a new method of calculating the HDI. The following three indices are used:

1. Life Expectancy Index (LEI) $= \frac{LE - 20}{83.4 - 20}$
2. Education Index (EI) $= \frac{\sqrt{MYS \cdot EYSI}}{0.951}$
 - 2.1 Mean Years of Schooling Index (MYSI) $= \frac{MYS}{13.2}$
 - 2.2 Expected Years of Schooling Index (EYSI) $= \frac{EYS}{20.6}$

$$= \frac{\ln(GNI_{pc}) - \ln(100)}{\ln(107,721) - \ln(100)}$$

3. Income Index (II)

Finally, the HDI is the geometric mean of the previous three normalized indices :

$$HDI = \sqrt[3]{LEI \cdot EI \cdot II}$$

LE : Life expectancy at birth

MYS : Mean years of schooling (Years that a 25-year-old person or older has spent in schools)

EYS : Expected years of schooling (Years that a 5-year-old child will spend with his education in his whole life)

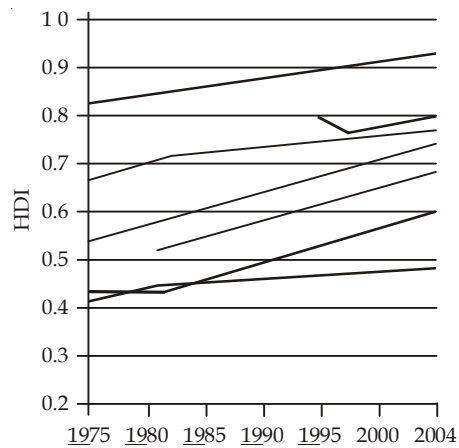
GNI_{pc} : Gross national income at purchasing power parity per capita

*Task*

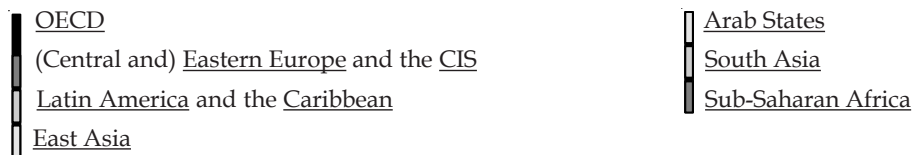
What is the full form of HDI?

3.3 Dimensions and Calculation

Notes



HDI trends between 1975 and 2004



This is the methodology used by UNDP up until its 2011 report.

The formula defining the HDI is promulgated by the United Nations Development Programme (UNDP). In general, to transform a raw variable, say, x , into a unit-free index between 0 and 1 (which allows different indices to be added together), the following formula is used :

$$x\text{-index} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

- where $\min(x)$ and $\max(x)$ are the lowest and highest values the variable x can attain, respectively.

The Human Development Index (HDI) then represents the uniformly weighted sum with $\frac{1}{3}$ contributed by each of the following factor indices :

- Life Expectancy Index = $\frac{LE - 25}{85 - 25}$
- Education Index = $\frac{2}{3} \times ALI + \frac{1}{3} \times GEI$
 - Adult Literacy Index (ALI) = $\frac{ALR - 0}{100 - 0}$
 - Gross Enrollment Index (GEI) = $\frac{CGER - 0}{100 - 0}$

Notes

$$\bullet \quad \text{GDP} = \frac{\log(\text{GDP}_{pc}) - \log(100)}{\log(40000) - \log(100)}$$



Did u know? Other organizations/companies may include Democracy Index, Population, etc. which produces different number of HDI.

Self-Assessment

1. Fill in the blanks:

- (i) The origins of HDI are found in the annual Human Development reports of the
- (ii) The is a composite statistic.

$$(iii) \quad \text{GDP} = \frac{\log(\text{GDP}_{pc}) - \log(100)}{\log(\text{.....}) - \log(100)}$$

3.4 Future HDI Projections

The origins of the HDI are found in the annual Development Reports of the United Nations Development Programme (UNDP). These were devised and launched by Pakistani economist Mahbub ul Haq in 1990 and had the explicit purpose “to shift the focus of development economics from national income accounting to people centered policies”. To produce the Human Development Reports, Mahbub ul Haq brought together a group of well-known development economists including: Paul Streeten, Frances Stewart, Gustav Ranis, Keith Griffin, Sudhir Anand and Meghnad Desai. But it was Nobel laureate Amartya Sen’s work on capabilities and functionings that provided the underlying conceptual framework. Haq was sure that a simple composite measure of human development was needed in order to convince the public, academics, and policy-makers that they can and should evaluate development not only by economic advances but also improvements in human well-being. Sen initially opposed this idea, but he went on to help Haq develop the Index. Sen was worried that it was difficult to capture the full complexity of human capabilities in a single index but Haq persuaded him that only a single number would shift the attention of policy-makers from concentration on economic to human well-being.

The list of countries, ranked by their anticipated Human Development Index (HDI) in 2010–2030, was published in 2010 by the Human Development Report Office of the United Nations Development Programme (UNDP), as part of its Human Development Research Paper Series. The Human Development Research Paper (HDRP) Series is a medium for sharing recent research commissioned to inform the global Human Development Report, which is published annually, and further research in the field of human development. The HDRP Series is a quick disseminating, informal publication whose titles could subsequently be revised for publication as articles in professional journals or chapters in books. The authors include leading academics and practitioners from around the world, as well as UNDP researchers. The findings, interpretations and conclusions are strictly those of the authors and do not necessarily represent the views of UNDP or United Nations Member States. Moreover, the data may not be consistent with that presented in Human Development Reports.

For this Human Development Report Paper, the authors projected the HDI for every country which had a complete data series for the upcoming twenty years, whereas the HDI projection used projections of the components conducted by agencies that provide the UNDP with data for the HDI. The HDI list contains 81 countries, most of which are expected to have a “Very High” HDI by 2025.

In October 2009, the United Nations Development Programme published (in its 2009 Human Development Report) its last country list by Human Development Index (HDI), for 2007, classifying the countries into four categories, the first one of which is the group of countries having a “Very

High” HDI. Half a year later, in April 2010, the Human Development Report Office provided the 2010–2030 HDI projections (quoted in September 2010, by the United Nations Development Programme, in the Human Development Research paper 2010/40). These projections were reached by re-calculating the HDI, using (for components of the HDI) projections of the components conducted by agencies that provide the UNDP with data for the HDI.

The HDI was projected for all countries for which there was a complete data series for the 2010–2030 period. For example, the HDI was projected for every “non-tiny” country (i.e. for every country whose population is more than 800,000), that had a “Very High” HDI (i.e. an HDI of 900 or higher), in the 2009 Human Development Report. The HDI was not projected for countries for which there was no complete data series for the 2010–2030 period; Hence, the projection ignores countries which are not UN members (Hong Kong being an exception), and also ignores all “tiny” countries (among which seven had a “Very High” HDI in the 2009 Human Development Report: Andorra, Barbados, Brunei, Iceland, Liechtenstein, Luxembourg and Malta). All non-“tiny” UN members for which no projection was made, didn’t have a “Very High” HDI in the 2009 Human Development Report, although ten of them had (in the 2009 Human Development Report) a “High” HDI (i.e. 800 or higher): Albania, Belarus, Bosnia Herzegovina, Lebanon, Macedonia, Mauritius, Oman, Panama, Trinidad and Tobago, Uruguay.

According to these projections, Japan will lead among countries in the data set, with an HDI of 998 in 2030.

3.5 Physical Quality of Life Index (PQLI)

The **Physical Quality of Life Index (PQLI)** is an attempt to measure the quality of life or well-being of a country. The value is the average of three statistics : basic literacy rate, infant mortality, and life expectancy at age one, all equally weighted on a 0 to 100 scale. It was developed for the Overseas Development Council in the mid-1970s by Morris David Morris, as one of a number of measures created due to dissatisfaction with the use of GNP as an indicator of development. PQLI might be regarded as an improvement but shares the general problems of measuring quality of life in a quantitative way. It has also been criticized because there is considerable overlap between infant mortality and life expectancy.

Steps to Calculate Physical Quality of Life:

- (1) Find percentage of the population that is literate (literacy rate).
- (2) Find the infant mortality rate. (out of 1000 births) INDEXED Infant Mortality Rate = $(166 - \text{infant mortality}) \times 0.625$
- (3) Find the Life Expectancy. INDEXED Life Expectancy = $(\text{Life expectancy} - 42) \times 2.7$



Caution Physical Quality of Life = $(\text{Literacy Rate} + \text{INDEXED Infant Mortality Rate} + \text{INDEXED Life Expectancy})$

In 1979, D. Morris constructed a composite Physical Quality of Life Index (PQLI). He found that most of the indicators were inputs to development process rather than result of the development process. These indicators reflected that economically less developed countries are simply underdeveloped versions of industrialized countries.

He, therefore, combines three component indicators of Infant Mortality, Life Expectancy and Basic Literacy to measure performance in meeting the basic needs of the people. However, the choice of indicators is

1. Life Expectancy Indicator (LEI)
2. Infant Mortality Indicator (IMI)
3. Basic Literacy Indicator (BLI)

Notes

These three indicators can be improved in a variety of ways. However, Prof. Morris used Life Expectancy (LE) at birth as the indicator. Infant mortality implies deaths before age one instead of life expectancy at birth. In case, the figure for life expectancy at age one was not available, it could be worked out by using a formula which relates life expectancy at birth, infant mortality and the proportion of children.

3.5.1 How to Normalize Indicators

We are familiar that life expectancy is measured in terms of years, infant mortality rate in terms of per thousand and basic literacy rate in terms of percentage. They can Indian Economic Development and Elementary Statistics not be simply added. Moreover, basic literacy can have a natural zero for minimum and 100 for maximum, thus there exists no natural minimum or maximum values for other indicators. For comparison, each of the levels should be normalized. Prof. Morris chose the best and worst levels in each of the three cases. In the case of positive indicators of life expectancy and basic literacy, the best is shown by the maximum and worst by the minimum. While in case of negative indicator of infant mortality, the best is denoted by the minimum and the worst by the maximum. For converting the actual levels of a positive variable into normalized indicators, first the minimum values are subtracted from the actual values and then the gap is divided by the range. For positive indicators, the formula is:

$$\text{Achievement Level} = \frac{\text{Actual Value} - \text{Minimum Value}}{\text{Maximum Value} - \text{Minimum Value}}$$

For negative indicator of infant mortality, actual value has to be subtracted from the maximum value and the gap if any has to be dividing by the range. The formula is

$$\text{Achievement Level} = \frac{\text{Minimum Value} - \text{Actual Value}}{\text{Maximum Value} - \text{Minimum Value}}$$

If not shell, there indicators are averaged to give what is called the Physical Quantity of life Index (PQLI).

$$\text{PQLI} = (1/3) (\text{LEI} + \text{IMI} + \text{BLI})$$

3.5.2 Choice of Minimum and Maximum Values:

In case of life expectancy and infant mortality, there exist no natural minimum and maximum values. The conversions from values to indices are linear. Put the actual value of these indicators of the country in the expression and get the reasonable indices as Physical Quantity of Life Index.

Self-Assessment

2. State whether the following statements are 'true' or 'false'.
 - (i) HDI for a sample of 150 countries shows a very high co-relation with logarithm of GDP per capita.
 - (ii) The physical quality of life Index is an attempt to measure the quality of life or well-being of a country.
 - (iii) Ratan Lan Basu does not criticises the HDI concept from a completely different angle.

3.6 Summary

- HDI was devised and launched by Pakistani economist Mahbub ul Haq and Indian economist Amartya Sen in 1990.
- The origins of the HDI are found in the annual Human Development Reports of the United Nations Development Programme (UNDP).
- Haq was sure that a simple composite measure of human development was needed in order to convince the public, academics, and policy-makers that they can and should evaluate development not only by economic advances but also improvements in human well-being.
- The index has also been criticized as "redundant" and a "reinvention of the wheel", measuring aspects of development that have already been exhaustively studied.

- Ratan Lan Basu criticises the HDI concept from a completely different angle.
- A few authors have proposed alternative indices to address some of the index's shortcomings.
- The Physical Quality of Life Index (PQLI) is an attempt to measure the quality of life or well-being of a country.

Notes**3.7 Key-Words**

- Index : a list of names or topics that one referred to in a book.
- Explicit : clear and easy to understand
- Expectancy : the state of expecting or hopint that 5th, especially 5th good or exciting.

3.8 Review Questions

1. What is Human Development Index? Explain.
2. Describe the dimensions and claculation of HDI.
3. What is physical quality of life index?
Explain. Also write the steps to calculate physical quality of life.

Answer: Self Assessment

1. (i) United Nations development programme
(ii) Human and Development Index (iii) 40000
2. (i) T (ii) T (iii) F

3.9 Further Readings**Books**

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 4: Economic Growth Models-I: Harrod-Domar Growth Model

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Objectives

Introduction

- 4.1 Background to the Harrod-Domar Growth Model
- 4.2 The Harrod Model (HM)
- 4.3 The Domar Model (DM)
- 4.4 Comparison of Harrod Model and Domar Model
- 4.5 Harrod-Domar Growth Model
- 4.6 Summary
- 4.7 Key-words
- 4.8 Review Questions
- 4.9 Further Readings

Objectives

After reading this unit students will be able to:

- Know about the background to the Harrod-Domar growth model.
- Explain the Harrod model and Domar model.
- Compare between Harrod model and Domar model.
- Understand Harrod-Domar Growth model.

Introduction

There are many theories which have tried to explain the process of economic growth. These theories are also called growth models. Growth models set out the quantitative relationship among the critical variables in a rigorous form. Different economists have different opinions on the fact that which factors are most important in determining the rate of economic growth. Accordingly, each economist has formulated a different growth model. In this chapter, Harrod-Domar model has been explained.

4.1 Background to the Harrod-Domar Growth Model

Two economists R.F. Harrod and E.D. Domar worked almost concurrently to develop this model of economic growth. The ideas in the two models are different in details but are so similar in their essence that the two models have got integrated and are presented as Harrod-Domar Model.

HDM considered demand as well as supply side of the investment process and hence, integrated the classical and Keynesian analysis.

Essence of the Model

If there is increase in productive capacity of the economy without parallel increase in real national income, it may lead to under-utilization of new capital, there may be lack of other factors of production or the new capital may be substituted for labour. In simple words, unless and until capital formation and increase in real national income go side by side, growth will not sustain for long.

Assumptions of the Model

1. There is full employment equilibrium of national income initially.
2. No government interference.
3. It is a closed economic model.
4. No lags in adjustment.
5. APS and MPS are equal.
6. Capital output ratio and propensity to save are constant.

Self-Assessment

1. Fill in the blanks:
 - (i) Two economists R.F. Harrod and worked almost concurrently to develop the model economic growth.
 - (ii) considered demand as well as supply side of the investment process and hence, integrated the classical and Keynesian analysis.
 - (iii) Unless and until capital formation and increase in real national income go side by side will not sustain.
 - (iv) There is full equilibrium of national income initially.
 - (v) Capital output and propensity to save are constant.

4.2 The Harrod Model (HM)

R.F. Harrod showed through his model that steady growth rate may be achieved with fixed capital-output ratio and fixed propensity to save. He also explained the conditions that need to be fulfilled to maintain this steady growth rate. He further elaborated how natural resources put a ceiling on the growth rate of the economy.

Statement of the Model: It is based on three growth rates:

- (a) **Actual Growth Rate (G):** It is the first fundamental equation of Harrod Model. It is:

$$G = s$$

Where, G = annual growth rate $(\Delta Y/Y)$

C = marginal capital output ratio $(I/\Delta Y)$

S = APC

Equation 1 simply explains that savings = investment. It can be shown by substituting the values of G , C and S in equation 1.

$$G = S$$

Substituting the values,

$$(\Delta Y/Y) * (I/\Delta Y) = S/Y$$

$$I/Y = S/Y$$

$$I = S$$

- (b) **Warranted Growth Rate (G_w):** It is the growth rate which is attainable at full employment level. The equation for warranted growth can be stated as follows:

$$G_w C_r = s$$

Where G_w is warranted growth rate

C_r is capital formation required to maintain it.

s = APS

Notes

Warranted growth rate equation in the model implies that actual investment must be equal to expected investment to attain stable growth. It will happen when:

$$G = G_w$$

$$C = C_r$$

State of Disequilibrium

When $G > G_w$: In this situation, income is growing faster than output, hence, the economy would face inflation.

When $G < G_w$: In this situation, output is growing faster than income, hence, there would be deficient demand.

When $C < C_r$: In this situation, the actual amount of capital will be less than required capital. Hence, there will be deficiency in capital. This will lead to fall in output and thereby inflation.

When $C > C_r$: In this situation, the amount of capital available is larger than required capital and hence, MEC will fall that will lead economy into the depression.

- (c) **Natural Growth Rate:** It is the maximum growth rate that can be attained by an economy, given the natural resources. It is determined by macro variables like population technology, natural resources etc.

Interaction between three equations: There are three possibilities.

- (a) $G_w = G_n$: In this situation, steady growth would prevail in the economy but this happens rarely. More frequently the two of these are unequal.
- (b) $G_w > G_n$: This is a situation in which many resources of the economy would be lying unemployed and hence, there is a scope for increasing the rate of growth through suitable government policies.
- (c) $G_w < G_n$: Since the economy has already attained full employment level, such a situation will create inflation in the economy.



Notes

Capital-output ratio and labour-output ratios are constant.

Policy Implications of the Model

It is advisable to make such policy instruments that help to decrease the savings if $G_n < G_w$ as it will increase AD and hence new equilibrium will be at a higher level. But if $G_n > G_w$, then decrease in savings will lead to inflation and hence it should be increased.

The Harrod Model and Trade Cycles

- (a) When $G_w > G_n$ at full employment level, there will be recession in the economy.
- (b) When $G_w < G_n$ at full employment level, there probabilities.
- (i) There is a strong probability that in the long run it will ride above G_n and if so happens there will be vicious spiral of depression after attainment of full employment level.
- (ii) If G_w does not overtake G_n in the long run, there will be inflation in the economy.

Critique of the Harrod Model

1. In real scenario, there is no evidence of the existence of fixity of production function, saving ratio, growth rate of labour force as assumed by Harrod.
2. There are many other factors leading to economic growth like improvement in technology which Harrod model does not discuss.

4.3 The Domar Model (DM)

The Domar model has tried to explain that what should be the growth rate to maintain full employment equilibrium in the economy? Domar Model has explained the conditions which need to be satisfied to attain the given goal.

Statement of the Model

Investment in the economy affects AD as well as AS because on the one hand, investments increases productive capacity, and at the same time it generates income through multiplier effect.

The equation for demand side is

$$Y_d = I/d$$

Where, Y_d is the level of effective demand at full employment level.

I is net investment

d = Marginal Propensity to Save

It is clear from the equation that there is direct relation between effective demand and level of investment and inverse relation between effective demand and MPC.

The equation for supply side of investment is

$$Y_s = \sigma k$$

Where, Y_s is the level of productive capacity at full employment level.

σ is the productive capacity of capital;

k is real capital

Equilibrium: Economy is in equilibrium where $Y_d = Y_s$

$$\text{Or } I/d = \sigma k$$

$$\text{Or } I = d \sigma k$$

Equation derived above is the equation to be satisfied for steady rate of economic growth.

From this **condition of maintaining steady growth** can be explained. If demand and supply change, the increment equation for the two can be stated as follows:

$$\Delta Y_d = \Delta I/d \quad (d \text{ is not changed because it is assumed to be constant})$$

$$\Delta Y_s = \sigma \Delta K \quad (\text{change in real output will be equal to the product if change in real capital.}$$

ΔK , multiplied by productivity of capital, σ , which is assumed to be constant).

If we substitute I in place of ΔK , then

$$Y_s = \sigma I$$

Equilibrium: In Equilibrium,

$$\Delta Y_d = \Delta Y_s$$

$$\text{or } \Delta I/d = \sigma I$$

Cross multiplication will give us:

$$\Delta I/I = \sigma d$$

This is the equation for **Maintaining Steady Growth** that growth rate of investment should be equal to product of MPC (d), and Productivity of Capital (σ).

Notes

Numerical Example: Let σ be 20% per year,

$$d = 10\%$$

$$Y = \$ 200 \text{ billion a year}$$

Then we need an investment of

$$I = d \sigma k$$

to maintain a level of full employment steady economic growth rate.

$$I = 200 * 10 / 100 \text{ (because } \sigma k = Ys)$$

$$= 20 \text{ billions}$$

This will raise output by σ .

$$20 * 20\% = 4 \text{ billion.}$$

The relative rise in income will be equal to

$$\frac{Y^* \sigma^* d}{Y} = 200 * 20\% * 10\% / 200$$

$$= 20\% * 10\% = 2\%$$

Therefore, in order to maintain full employment in the economy, real output must increase by 2% p.a.

Assumption of the Model

The assumptions of the Domar Model are as follows:

1. MPC is constant; hence, income is determined by investment.
2. Employment is a function of utilization ratio i.e. the ratio between actual output and productive capacity.
3. Productive capacity can be increased by at a given ratio via past and present investment.



Did u know? Investment depends upon output growth and entrepreneur confidence.

Policy Implication of the Model

Sufficient investment is required to attain dual objective:

- (a) To utilize the resources of the economy fully.
- (b) To ensure that economy will be able to produce more in the future according to increased demand.

Self-Assessment

2. Multiple choice questions:

Choose the correct option

- (i) The first fundamental equation of Harrod model is

(a) $GC = S$ (b) $GC = b$ (c) $GC = K$ (d) $GC = d$

- (ii) The equation for warranted growth can be stated as

(a) $G = Gw$ (b) $GwCr = s$ (c) $Gw > Gn$ (d) $C > Cr$

- (iii) is the maximum growth rate that can be attained by an economy given the natural resources.

- (a) Natural growth rate (b) Trade growth rate
(c) Critical growth (d) Steady growth rate

(iv) is constant, hence, income is determined by investment.

(a) APC (b) CRC (c) MPC (d) DRD

(v) depends upon output growth and entrepreneur confidence

(a) Investment (b) Implications (c) Policy (d) Objective

Notes

4.4 Comparison of Harrod Model and Domar Model

Similarities

The two models start different but reach at similar conclusions. What Harrod called as Warranted Growth Rate (G_w), is the same what Domar called full employment rate of growth, ($d\sigma$)

Proof : $d = S/Y$

or $S = dY \rightarrow 1$

$$\sigma = \Delta Y/I$$

or $\Delta Y = I \sigma \rightarrow 2$

Since $S = I$, substituting S for I in equation. (2), we have,

$$\Delta Y = dY \sigma \quad (\text{because } S = dY)$$

or $\Delta Y/Y = d \sigma$

Therefore, $G_w = d \sigma$ (because $G_w = \Delta Y/Y$)

Hence, Harrod's Warranted growth rate is same as

Domar's full employment growth rate $d\sigma$.

Dissimilarities

Basis	Harrod's Model	Domar's Model
Long Run Problem	Shortage of labour deflecting growth	Under investment gradually weakens growth
Labour input	Labour input is the key element in determining natural rate of growth	Non-availability of suitable labour input may trigger scrapping of investment
Centrifugal force from equilibrium	Adjustment process in the long run is unstable	Investment incentives are continuously undermined
Explanation for fixed capital output ratio	Explained through fixed interest rate, low substitutability etc.	No explanation is offered just assumed for convenience
State of Economy	Unemployment of labour is an issue	Idle productive capacity is an issue

4.5 Harrod-Domar Growth Model

Substance of the Model

In short, the highlights of HDM are as follows:

1. In HDM, Investment in the economy plays a dual role. It affects AD as well as AS because on the one hand, investments increases productive capacity, and at the same time it generates income through multiplier effect.

Notes

2. With the increase in capacity the economy can produce greater output and greater employment, depending on the level of MPS.
3. There are three growth rates: Actual Warranted and Natural; the equality amongst the three ensures full employment of labour and capital stock.
4. The theory also explains trade cycles. When there is $G > G_n$, then there will be unemployed resources in the economy, hence, the economy will be in the recovery phase.
When $G = G_n$, there will be full employment of resources.
When $G < G_n$, there will be slump in the economy.
5. Business cycles are taken as deviations from the path of steady growth. These deviations cannot go on infinitely. There are constraints on 'upper' and 'lower' limit. Effective demand can't be more than full employment level, hence, full employment ceiling is the upper limit and effective demand can't be less than autonomous consumption. It acts as a lower limit. The actual growth rate fluctuates between these two limits.

Limitations of the Model

This model has been criticized on the following grounds:

1. Assumption of constant propensity to save and capital-output ratio is questioned by many economists. If these parameters change, there would be change in requirements of steady growth.
2. It is well known aspect that as an economy grows, there is change in the relative importance of the three sectors, namely, primary, secondary and tertiary.
3. HDM assumes the requirements of capital and labour per unit of output are constant i.e. capital-output ratio and labour-output ratios are constant. Actually, different factors of productions are not perfect substitutes but can be substituted for each other to a limited extent.
4. The HDM is worried about steady growth but is neglecting the rate of growth. However, the aim of developing countries is to increase rate of growth. Developed countries might take steady growth as an important objective but developing countries are not as bothered for stability as they are for the rate of growth.
Rather, they would get willing to compromise stability to attain a higher rate of growth.
5. HDM model is nowhere incorporating the role of government in influencing the growth process in the economy as it is based on laissez-faire policy. Hence, it is not relevant for developing economies particularly those in which government is playing a dominating role like India and China.



Notes

HDM is constructed on basis of aggregates and can not show the inter-relations between the sectors and hence does not demonstrate structural changes.

Self-Assessment

3. State whether the following statements are 'true' or 'false'.
 - (i) The two models start differently but reach at similar conclusions.
 - (ii) In HDM, investment in the economy plays a single role.
 - (iii) There are three growth rates: Actual, warranted and natural
 - (iv) It is relevant for developing economies particularly those in which government is playing a dominating role like India and China.
 - (v) Effective demand Can't be more than full employment level.

4.6 Summary

Notes

- Two economists R.F. Harrod and E.D. Domar worked almost concurrently to develop this model of economic growth.
- HDM considered demand as well as supply side of the investment process and hence, integrated the classical and Keynesian analysis.
- If there is increase in productive capacity of the economy without parallel increase in real national income, it may lead to under-utilization of new capital, there may be lack of other factors of production or the new capital may be substituted for labour.
- R.F. Harrod showed through his model that steady growth rate may be achieved with fixed capital-output ratio and fixed propensity to save. He also explained the conditions that need to be fulfilled to maintain this steady growth rate.
- Warranted Growth Rate (G_w): It is the growth rate which is attainable at full employment level.
- Investment in the economy affects AD as well as AS because on the one hand, investments increases productive capacity, and at the same time it generates income through multiplier effect.
- Equation derived above is the equation to be satisfied for steady rate of economic growth.

4.7 Key-words

- Growth : An increase in economic activity.
- Economic : Connected with the trade, industry and development of wealth of a country.
- Steady : Developing growing gradually and in an even and regular way.
- Equilibrium : a state of balance.

4.8 Review Questions

1. What is Harrod-Domar Growth model
2. How does the Harrod model explain the occurrence of trade cycles?
3. State the Conditions necessary for steady growth.
4. State the difference between Harrod Model and Domar model
5. What are the basic features of Harrod Domar Model of growth? Also state the limitations of the model.
6. What are policy implications of the HDM?

Answer: Self Assessment

- | | | | | |
|----|-----------------------------|----------|--------------|-----------------|
| 1. | (i) E.D. Domar
(v) ratio | (ii) HDM | (iii) growth | (iv) employment |
| 2. | (i) a | (ii) b | (iii) c | (iv) a |
| 3. | (i) T
(v) T | (ii) F | (iii) T | (iv) F |

Notes

4.9 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 5: Neo-Classical Growth Models

Notes

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- 5.1 Production and Investment
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Objectives

The objectives of this unit can be summarized as below:

- to know about the solow model.
- to describe applications of the Neo-classical growth model money in the Neo-classical growth model.
- to understand the convergence and poverty traps.

Introduction

Following the Lucas critique, macroeconomists have become much increasingly concerned with the microfoundations for their models and, in particular, with the **intrinsic dynamics** of consumption and investment decisions. One motivation for this is that, under rational expectations the short-run AS-AD model displays very little persistence in response to shocks and therefore does not provide a complete explanation for business cycles. Thus, microeconomic models of dynamics consumption choices and investment started to be built into the mainstream macroeconomic framework. In these notes, I will lay out the basics of these models but I will try to keep things as simple as possible. The cost to doing this is perhaps a loss in the degree of realism, but additional features (*e.g.* heterogeneity, borrowing constraints, etc.) can and have been added to address many of these concerns.

To start with it is useful to develop a simple, discrete time version of the neoclassical growth (Ramsey-Cass-Koopmans) model. This effectively extends the Solow growth model (which you should have come across before) by allowing for endogenous consumption-savings choices along the lines described earlier.

Notes

5.1 Production and Investment

There are three key assumptions :

- Output, Y_t , is produced using capital, K_t , and labour, L_t , according to a production function given by

$$Y_t = F(K_t, L_t)$$

It is assumed that the production function is increasing and concave in both K and L , and that it exhibits **constant returns to scale**. This means that if both inputs are doubled, output doubles. More generally, for any number $\lambda > 0$,

$$F(\lambda K_t, \lambda L_t) = \lambda F(K_t, L_t) = \lambda Y_t.$$

One important example of such a production function is the Cobb-Douglas production function

$$Y_t = K_t^\alpha L_t^{1-\alpha},$$

where $0 < \alpha < 1$.

- Capital is subject to a constant rate of depreciation δ per period, so that capital accumulates according to the process

$$\Delta K_t = K_{t+1} - K_t = I_t - \delta K_t.$$

Here I_t represents total new investment in fixed capital.

- The markets for labour and capital inputs are competitive, with all firms and factor owners being paid their marginal product. Given a wage per unit of labour, w_t , and a real rate of interest r_t , this implies that

$$\frac{\partial F}{\partial L} = w_t$$

and

$$\frac{\partial F}{\partial K} = r_t + \delta.$$

The second condition states that the marginal product of capital equal the **user cost of capital**. This is the opportunity cost of financing the capital investments of the firm rather than investing in the bond market, say, plus the depreciation of that capital. In the Cobb-Douglas case, these conditions are

$$(1-\alpha)K_t^\alpha L_t^{1-\alpha} = w$$

$$\alpha K_t^{\alpha-1} L_t^{1-\alpha} = r_t + \delta.$$

Notice that multiplying the first condition by L_t and the second by K_t gives

$$(1-\alpha)K_t^\alpha L_t^{1-\alpha} = w L_t$$

$$\alpha K_t^\alpha L_t^{1-\alpha} = (r_t + \delta) K_t.$$

Since $Y_t = K_t^\alpha L_t^{1-\alpha}$, it follows that α is equal to the share of total output that is earned by capital owners and $1-\alpha$ is the share going to labour. Both factors are owned by households (but the distribution of ownership need not be equal).

Intensive Form

Notes

It is convenient to express things in “per worker” terms : this is often referred to as the intensive

form. If we let $\lambda = \frac{1}{L_t}$ then with constant returns to scale we have

$$F\left(\frac{K_t}{L_t}, 1\right) = \frac{1}{L_t} F(K_t, L_t) = \frac{Y_t}{L_t}.$$

Now let $y_t = Y_t/L_t$ and $k_t = K_t/L_t$ and we can write this as

$$y_t = f(k_t) = F(k_t, 1).$$

In the Cobb-Douglas case we have

$$\frac{Y_t}{L_t} = \frac{K_t^\alpha L_t^{1-\alpha}}{L_t} = \left(\frac{K_t}{L_t}\right)^\alpha$$

or
$$y_t = k_t^\alpha.$$

We can also express the input pricing conditions in per worker terms. In the Cobb-Douglas case these are

$$(1-\alpha)k_t^\alpha = w_t$$

$$\alpha k_t^{\alpha-1} = r_t + \delta$$

Note that the marginal product of capital is decreasing with the capital-worker ratio since $\alpha - 1 < 0$. Finally, we can express the capital accumulation process in per worker terms. If population and labour force growth is zero then this is just

$$\Delta k_t = k_{t+1} - k_t = i_t - \delta k_t.$$

where $i_t = I_t/L_t$.

5.2 A Basic Version

Here I will lay out a basic version of the model in discrete time which makes the following assumptions :

- The number of households, N_t is equal to the number of workers, L_t .
- Zero population growth so that the potential supply of workers is fixed at N .
- Labour and capital markets are competitive and clear every period. This means that $L_t = N$ and that investment equals savings : $i_t = y_t - c_t$.
- There is no technical change.
- Households have identical CES utility functions
- Production is described by the Cobb-Douglas production function
- Household's are assumed to exist indefinitely, so that $T \rightarrow \infty$
- The market discount factor from the perspective of time 0 is given by

$$D_t = \prod_{s=0}^t \left(\frac{1}{1+r_s} \right)$$

Notes

Given these assumption, the competitive equilibrium can be described by a system of 7 equations:

$$y_t = c_t + i_t \quad \dots (1)$$

$$y_t = k_t^\alpha \quad \dots (2)$$

$$\Delta k_t = i_t + \delta k_t \quad \dots (3)$$

$$\frac{c_t}{c_t - 1} = [\beta(1 + r_t)]^\sigma \quad \dots (4)$$

$$\sum_{t=1}^{\infty} D_t c_t = k_1 + \sum_{t=1}^{\infty} D_t w_t \quad \dots (5)$$

$$r_t = \alpha k_t^{\alpha-1} - \delta \quad \dots (6)$$

$$w_t = (1 - \alpha) k_t^\alpha \quad \dots (7)$$

This looks complicated, but notice that we can combine equation (1), (2) and (3) to get

$$\Delta k_t = k_t^\alpha - c_t - \delta k_t \quad \dots (8)$$

This equation shows how the change in the capital stock depends on the current stock and consumption. Also, we can combine (5) and (6) to get

$$\frac{c_t}{c_t - 1} = [\beta(1 + \alpha k_t^{\alpha-1} - \delta)]^\sigma$$

Subtracting 1 from both side gives

$$\frac{\Delta c_t}{c_t - 1} = [\beta(1 + \alpha k_t^{\alpha-1} - \delta)]^\sigma - 1 \quad \dots (9)$$

This equation shows how the growth in consumption depends on the time t capital stock. Notice that since $\alpha - 1 < 0$, consumption growth decreases with k_t . This is because when k_t increases, the interest rate falls due to diminishing returns to capital per worker, which induces households to raise their consumption today relative to tomorrow.

Equations (14) and (15) can be represented on a **phase diagram**. To do this we need to plot the combinations of consumption and capital such that $\Delta k = 0$ and those for which $\Delta c = 0$.

- The $(\Delta k_t = 0)$ locus is given by

$$c_t = k_t^\alpha - \delta k_t$$

This relationship is illustrated in Figure 3 (where $\dot{k} = \Delta k$). To understand its shape, note that the slope of this locus is given by

$$\frac{dc_t}{dk_t} = \alpha k_t^{\alpha-1} - \delta = \frac{\alpha}{k_t^{1-\alpha}} - \delta.$$

When k_t is close to zero, the first term (the MP of capital) is very large, so the slope must be steep and positive. As k_t increases, the first term decreases, so that the slope declines and eventually

turns negative. The peak of this locus occurs where $\frac{dc_t}{dk_t} = 0$. That is where

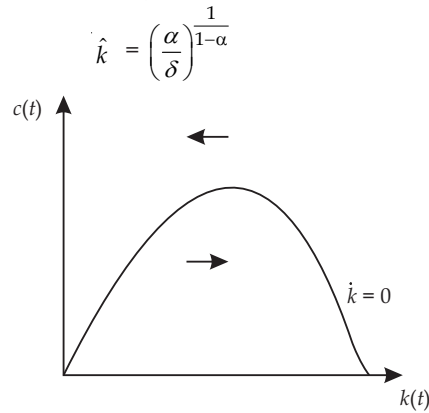


Figure 5.1: $\Delta k = 0$ locus

What are the implied dynamics above and below this curve? Look at equation (14). Starting from values of c_t and k_t such that $\Delta k_t = 0$, suppose we increase c_t , holding k_t fixed. Then it must be the case that $\Delta k_t < 0$. This implication is illustrated by the leftward pointing arrow in Figure 1. Similarly, if we are below the curve, $\Delta k_t > 0$.

- The $(\Delta c_t = 0)$ locus is given by

$$\beta(1 + \alpha k^{\alpha-1} - \delta) = 1$$

Solving for k_t this is

$$\alpha k_t^{\alpha-1} = 1/\beta - 1 + \delta$$

$$k^* = \left(\frac{\alpha}{1/\beta - 1 + \delta}\right)^{\frac{1}{1-\alpha}}$$

Thus, this locus can be represented as a vertical line at k^* . Note that since $\beta = \frac{1}{1+\rho}$ (see above) we can also write this as

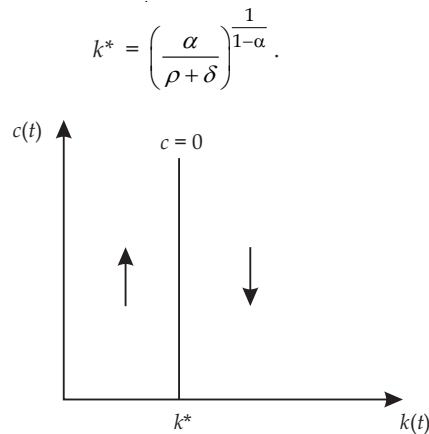


Figure 5.2: $\Delta c = 0$ locus

Notes

What are the implied dynamics to the left and right of this curve? Look at equation (15). Starting from k^* , where $\Delta c = 0$, suppose we increase k_t . Since $\alpha - 1 < 0$, it follows that $\Delta c_t < 0$. This implication is illustrated by the downward pointing arrow in Figure 2. Intuitively, an increase in k causes the interest rate and hence consumption growth to fall. Similarly, to the left of k^* , $\Delta c_t > 0$.

Figure 3 depicts the complete **phase diagram** for this neoclassical growth model. The arrows depict the combined forces on consumption and capital per worker implied by the Euler equation and the capital accumulation process. The intersection of the $(\Delta c = 0)$ locus and the $(\Delta k = 0)$ locus, S , represents the only combination of c_t and k_t such that there is no tendency for either to change over time. This is the unique **steady state** of the economy it is given by the combination (c^*, k^*) which satisfies

$$k^* = \left(\frac{\alpha}{\rho + \delta} \right)^{\frac{1}{1-\alpha}}$$

$$c^* = k^{*\alpha} - \delta k^*.$$

Note that as shown in Figure 3 the $(\Delta c = 0)$ intersects the $(\Delta k = 0)$ locus to the left of the peak.

Note that this must be the case since $k^* < \hat{k}$. Consequently, long run optimal consumption in the steady state is below its feasible maximum. How can this be optimal if utility is increasing in consumption? The reason is that households discount the future (at rate ρ) and therefore always want to consume more in the short-run. In doing so, they invest less and accumulate less capital, which restricts their long run consumption.

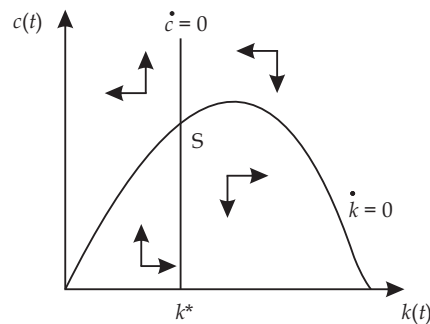


Figure 5.3 : Phase Diagram

Transitional Dynamics

Is it the case that if we start away from this steady state, that the economy will converge back to it? To determine this we need to explore the economy's **transitional dynamics**. To understand these dynamics it is important to note a key distinction between consumption and capital. Capital, k_t is a **state variable** — although it can be accumulated or decumulated over time, at any point in time it is **pre-determined** by past investments. Consumption c_t on the other hand is a **jump variable** — it is not restricted to any particular value by things that have been done in the past, and can always be adjusted immediately to reflect new information regarding a household's future wealth (whereas k_t can't). Suppose we start with some capital stock, k_0 . While the Euler equation tells us how consumption should optimally

grow from period to period, it does not pin down the initial level, c_0 . So what value of c_0 should households choose?

So far, we have not imposed the **intertemporal budget constraint** (11) on the household. However, we know that this must be satisfied, and it is this additional equation which pins down the initial value of c_0 . If consumption levels are too high, the household will be consuming more than its wealth, if they are too low, it will be consuming too little. In fact, given the Euler equation and the capital accumulation process, there is *only one* value of c_0 that satisfies the budget constraint and it is the one that places the economy on a trajectory towards the steady state. To understand this, consider Figure 4.

Given k_0 , suppose that households were to choose an initial consumption level like that at A. From this point, according to the implied dynamics, consumption would grow and capital would decumulate over time. Eventually, it would become negative and consumption would grow indefinitely. This makes no sense. It implies that the households present value of consumption exceeds its wealth and so is inconsistent with the household budget constraint. Similarly, from a point like B, although k would initially rise eventually we enter the same dynamic region as A and the budget constraint is violated. At the opposite extreme, suppose we start with a very low level of consumption like that at C. Eventually, as shown, this economy crosses the $\Delta c = 0$ locus and the implied dynamics push it away from the steady state. The economy eventually would reach a situation with zero consumption, even though the capital stock (and output) is positive. This corresponds to households being well inside their budget constraint, and cannot be optimal.

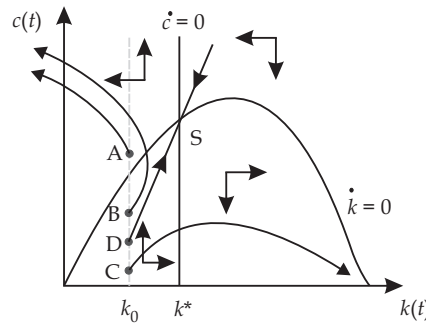


Figure 5.4: Transitional Dynamics

There is however, a unique level of consumption that places the economy at D. From this point, the implied dynamics push the economy towards the steady state. This is the only situation which is consistent with the budget constraint because it implies that in the long run consumption is exactly equal to output (less depreciation). Any other initial consumption level will imply a violation of the budget constraint. The unique path towards the steady state is known as the **saddlepath trajectory**, and the economy must always be on it. Note that we can make similar arguments starting from a capital stock above k^* to derive a similar saddlepath above and to the right of S.

Formal Analysis of Log-Linearized Model

The non-linear system describing the dynamics of the model can be expressed as

$$c_t = k_t^\alpha + (1 - \delta)k_t - k_{t+1} \quad \dots (10)$$

$$\left(\frac{c_t}{c_{t-1}} \right)^{\frac{1}{\sigma}} = \beta \left(1 + \alpha k_t^{\alpha-1} - \delta \right) \quad \dots (11)$$

Notes

Recall that the steady state is described by

$$c^* = k^{*\alpha} - \delta k^*$$

$$1 = \beta [\alpha k^{*\alpha-1} + (1-\delta)]$$

We want to express the model in terms of log-deviations around the steady state

$$\hat{c}_t = \ln c_t - \ln c^*$$

$$\hat{k}_t = \ln K_t - \ln k^*$$

Note that if the log-deviation for any variable x is small, we can linearize using the rule :

$$x_t = e^{\hat{x}_t} x^* \approx (1 + \hat{x}_t) x^*$$

We can now proceed to linearize the system :

Aggregate resource constraint

$$(1 + \hat{c}_t) c^* = (1 + \alpha \hat{k}_t) k^{*\alpha} + (1 - \delta) (1 + \hat{k}_t) k^* - (1 + \hat{k}_{t+1}) k^*$$

$$\hat{c}_t c^* = \alpha \hat{k}_t k^{*\alpha} + (1 - \delta) \hat{k}_t k^* - \hat{k}_{t+1} k^*$$

$$\hat{c}_t c^* = (\alpha k^{*\alpha-1} + 1 - \delta) k^* \hat{k}_t - k^* \hat{k}_{t+1}$$

$$\hat{c}_t = \frac{k^*}{\beta c^*} \hat{k}_t - \frac{k^*}{c^*} \hat{k}_{t+1}$$

Euler equation :

$$1 + \frac{1}{\sigma} (\hat{c}_t - \hat{c}_{t-1}) = \beta \left((1 + (\alpha - 1) \hat{k}_t) \alpha k^{*\alpha-1} + 1 - \delta \right)$$

$$\frac{1}{\sigma} (\hat{c}_t - \hat{c}_{t-1}) = \beta ((\alpha - 1) \hat{k}_t) \alpha k^{*\alpha-1}$$

$$\hat{c}_t - \hat{c}_{t-1} = -\sigma (1 - \beta(1 - \delta)) (1 - \alpha) \hat{k}_t$$

The log-linearized system is then :

$$\hat{c}_t = \frac{k^*}{\beta c^*} \hat{k}_t - \frac{k^*}{c^*} \hat{k}_{t+1} \quad \dots (1')$$

$$\hat{c}_t - \hat{c}_{t-1} = -\sigma (1 - \beta(1 - \delta)) (1 - \alpha) \hat{k}_t \quad \dots (2')$$

Solution : The Method of Undetermined Coefficients

The solution to this linear system of equations must take the form :

$$\hat{k}_{t+1} = a_1 \hat{k}_t$$

$$\hat{c}_t = a_2 \hat{k}_t$$

That is, each endogenous variable in time t is a linear function of the state variable $\hat{k}_t$. Note in particular, that for this system to satisfy the transversality condition (*i.e.* converge to the steady state),

$\hat{k}_t$ must converge to zero. That is, we must have $a_1 < 1$ (this is the way the intertemporal budget constraint is imposed). We need to solve for the 2 unknown parameters (a_1, a_2) .

Substituting these posited solutions into the resource constraint we get

$$a_2 k_t = \frac{k^*}{\beta c^*} k_t - \frac{k^*}{c^*} a_1 k_t$$

This implies the unknown parameters must satisfy :

$$a_2 = \frac{k^*}{\beta c^*} - \frac{k^*}{c^*} a_1 \quad \dots (12)$$

From the Euler equation we have

$$a_2 \hat{k}_t - a_2 \hat{k}_{t-1} = -\sigma(1 - \beta(1 - \delta))(1 - \alpha) \hat{k}_t$$

$$a_2 \hat{k}_t - \frac{a_2}{a_1} \hat{k}_t = -\sigma(1 - \beta(1 - \delta))(1 - \alpha) \hat{k}_t$$

This tells us that the unknown parameters must satisfy :

$$a_2 - \frac{a_2}{a_1} = -\sigma(1 - \beta(1 - \delta))(1 - \alpha) \quad \dots (13)$$

This gives us 2 equations in 2 unknowns (12) and (13). Substituting out a_2 we get

$$\frac{k^*}{\beta c^*} - \frac{k^*}{c^*} a_1 - \frac{1}{a_1} \frac{k^*}{\beta c^*} + \frac{k^*}{c^*} = -\sigma(1 - \beta(1 - \delta))(1 - \alpha) \quad \dots (14)$$

Multiplying through by $a_1 \frac{c^*}{k^*}$ and re-arranging, this can be written as

$$a_1^2 - \gamma a_1 + \frac{1}{\beta} = 0$$

where

$$\gamma = 1 + \frac{1}{\beta} + \sigma \left(\frac{1}{\beta} - (1 - \delta) \right) (1 - \alpha) \frac{c^*}{k^*} > 1$$

Solving the quadratic equation for a_1 yields

$$a_1 = \frac{\gamma \pm \sqrt{\gamma^2 - \frac{4}{\beta}}}{2}$$

$$a_1 = \frac{\gamma}{2} \pm \sqrt{\left(\frac{\gamma}{2}\right)^2 - \frac{1}{\beta}}$$

Note that the product of these two (positive) roots is $\frac{1}{\beta} > 1$. It follows that the larger one must exceed

1, and so only the smaller one can possibly satisfy the convergence condition that $a_1 < 1$.

It follows that

Notes

$$\hat{a}_1 = \frac{\gamma}{2} - \sqrt{\left(\frac{\gamma}{2}\right)^2 - \frac{1}{\beta}}$$

Given this value of $\hat{a}_1$ we can go back and solve for $\hat{a}_2$:

$$\hat{a}_2 = \frac{k^*}{\beta c^*} - \frac{k^*}{c^*} \hat{a}_1$$

Note that the value of $\hat{a}_1$ dictates the rate at which k converges to the steady state. The closer it is to 1 the more slowly the system converges.

A Simple Parameterization

For annual data, typical parameter values are $\alpha = 0.36$, $\delta = 0.08$, $\beta = 0.96$ and $\sigma = 1$. It follows that

$$k^* = \left(\frac{0.36}{0.04 + 0.08} \right)^{1.56} = 3^{1.56} = 5.55$$

$$c^* = (5.55)^{0.36} - 0.44 = 1.41$$

and so

$$\gamma = 1 + 1.04 + (1.04 - 0.92)(0.64) \frac{1.41}{5.55} = 2.06$$

Thus

$$\hat{a}_1 = \frac{2.06}{2} - \sqrt{\left(\frac{2.06}{2}\right)^2 - 1.04} = 0.88$$

and

$$\hat{a}_2 = \frac{5.55}{1.41} (1.04 - 0.88) = 0.63$$

5.3 Fiscal Policy in the Neoclassical Growth Model

A Balanced – Budget Increase in Government Consumption

Suppose the government buys output of g_t per capital at time t . Assume that this government spending does not affect utility from private consumption nor does it affect future output (these are simplifying assumption, which could in principle be relaxed). The purchases are financed by **lump – sum** taxes equal to T_t – these taxes are independent of how much the household saves and do not affect labour supply conditions.¹ For now, we will assume that the government balances its budget every period and has no outstanding debt. It follows that

$$T_t = g_t.$$

Investment is then the difference between output, k_t^α , and the sum of private consumption, c_t , and government spending, g_t . It follows that the capital accumulation equation becomes

$$\Delta k_t = k_t^\alpha - c_t - g_t - \delta k_t.$$

Consequently, the ($\Delta k = 0$) locus becomes

$$c_t = k_t^\alpha - g_t - \delta k_t.$$

Because these taxes are not imposed on the returns to saving (see below), the Euler equation will be unaffected, but the household's intertemporal budget constraint becomes

$$\sum_{t=1}^T D_t c_t = A_1 + \sum_{t=1}^T D_t (w_t - g_t).$$

That is household wealth falls by an amount equal to the present value of future government spending (equal to taxes).

To understand the consequences of this, suppose that g_t is initially zero and then increases permanently to a constant level g . Then the ($\Delta k = 0$) locus shifts down by amount equal to g (for a given value of k , c_t must fall by g in order for Δk to stay equal to zero.) This is illustrated in Figure 5. Clearly, the steady state of the economy shifts down from S_1 to S_2 , implying a lower long run consumption level. But what does the transition path look like? We know that, in order to satisfy the intertemporal budget constraint, households **must** be on the saddlepath through S_2 once g_t has increased. However, at the time when the policy is changed, k is predetermined (it is a state variable), so the only way to get to the saddlepath is if consumption falls immediately by the full amount of the increase in government spending. In other words, there is no gradual transition and private consumption is **completely crowded out** by public consumption.

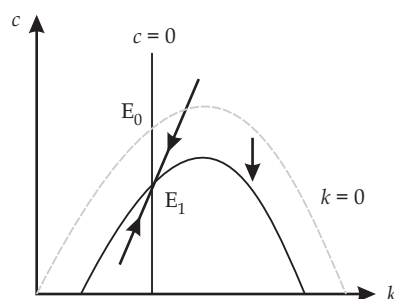


Figure 5.5 : Permanent Increase in Government Spending

Note that, in contrast to the static Classical model, the real interest rate remains the same since k does not change. Here, private consumption falls due to a pure wealth effect — the increase in g causes wealth to fall and the optimal way for households to respond is by lowering consumption immediately in proportion. The reason this is optimal is because with no change in r , consumption growth should remain unchanged (according to the Euler equation), so the initial level must fall in exact proportion to the fall in wealth.

Debt versus Tax Financing

Suppose now that the government can issue bonds (and thereby incur a debt) in order to finance any shortfall between g_t and T_t . Correspondingly whenever its **primary surplus**, $T_t - g_t$, exceeds the interest payments on its debt the government can pay down its existing debt, B_t (*i.e.* buy back bonds). It follows that the dynamic budget constraint faced by the government is given by

$$B_{t+1} = (1 + r) B_t + g_t - T_t.$$

Notes

We will impose the constraint that the public debt is **sustainable**. This amounts to saying that future surpluses must be sufficient to payoff the current debt load and the interest accruing on it.

Alternatively, this implies that there should be no debt beyond the planning horizon, *i.e.* the boundary condition $B_{T+1} = 0$ must hold. As we did with the households budget constraints, we can summarize this in the form of an **intertemporal budget constraint** :

$$\sum_{t=1}^T D_t g_t = -B_1 + \sum_{t=1}^T D_t T_t .$$

where D_t is the market discount factor. This can also be written as

$$\sum_{t=1}^T D_t (T_t - g_t) = B_1. \quad \dots (15)$$

Bonds are an asset from the perspective of private households. If they are to hold them then they must at least pay the same rate of return as capital. Thus, the best the government can do is set the interest rate on bonds equal to r_t . Since $A_t = k_t + B_t$, it follows that the household's budget constraint can be expressed as

$$\sum_{t=1}^T D_t c_t = k_1 + B_1 + \sum_{t=1}^T D_t (w_t - T_t)$$

Substituting for the initial debt level, B_1 , using (16) we can write this as

$$\begin{aligned} \sum_{t=1}^T D_t c_t &= k_1 + \sum_{t=1}^T D_t (T_t - g_t) + \sum_{t=1}^T D_t (w_t - T_t) \\ \sum_{t=1}^T D_t c_t &= k_1 + \sum_{t=1}^T D_t (w_t - g_t) \end{aligned}$$

But this is identical to the household budget constraint under period-by-period balanced budgets. In other words whether or not a given path of government consumption is financed by taxation or debt, as long as the government's intertemporal budget constraint is satisfied, the household's wealth is identical. That is, along as the debt is sustainable (and the rate of interest on debt is the same as on capital), the timing of taxation is irrelevant and the size of the debt is of no consequence. This implication was first hypothesized by the classical economist David Ricardo and is known as **Ricardian equivalence**. Consequently, the effect of an increase in g is identical to that illustrated in Figure 5.

It should be recognized that pure Ricardian equivalence is rather extreme and rests upon some very strong assumptions, such as the indefinite planning horizons of households, no uncertainty, perfect capital markets and full information. It is possible to generalize the basic model to account for some of these factors. Nevertheless, the basic qualitative nature of the result is still important : that due to the wealth effects of the implied future taxation, debt-financed increments in expenditure may reduce current consumption, even if current disposable income is unchanged.

Distortionary Taxation of Capital

Suppose that, instead of a lump-sum taxation, the government finances its spending through a proportional capital income tax at rate τ . In order to focus, exclusively on the effects of the distortion, assume that the revenue from the tax is remitted back to households in lump-sum fashion. This implies that their overall income remains unchanged, so that the ($\Delta k = 0$) locus does not shift down. The impact of the distortionary tax is then to lower the after-tax return earned by households on their savings, for a given capital stock. The after tax interest rate (assuming depreciation is tax-deductible) is then

$$\tilde{r}_t = (1 - \tau)\alpha k_t^{\alpha-1} - \delta$$

Substituting this into the household's Euler equation therefore gives

$$\frac{\Delta c_t}{c_{t-1}} = \left[\beta(1 - \delta + (1 - \tau)\alpha k_t^{\alpha-1}) \right]^\sigma - 1.$$

Setting this equal to zero yields the ($\Delta c = 0$) locus give by

$$\beta(1 - \delta + (1 - \tau)\alpha k_t^{\alpha-1}) = 1$$

$$\Rightarrow k^* = \left(\frac{\alpha(1 - \tau)}{1/\beta - 1 + \delta} \right)^{\frac{1}{1-\alpha}}.$$

Clearly, from this equation, an increase in the tax rate causes the long-run capital stock to decrease, shifting the ($\Delta c = 0$) locus to the left.

The effect of the tax is illustrated in Figure 6. The steady state shifts from E_1 to E_2 , so that in the long run, the increased tax results in a lower capital stock and lower consumption per capita. However, since capital cannot adjust instantaneously, the initial impact will be to cause consumption to rise to A on the saddlepath towards E_2 . As we have seen, this must be the case if the household satisfies its budget constraint. This short-run impact occurs because households start to save less of their income in response to the tax on the returns to saving. With a the resulting lower level of investment, over time both capital and consumption decline along the saddlepath until we reach the new steady state.

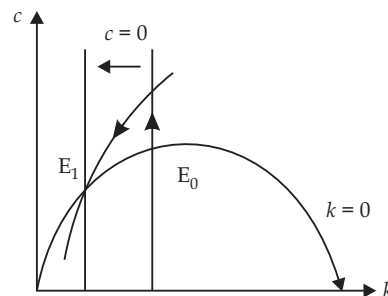


Figure 5.6: A Tax on Capital Income

5.4 Generalizations of the Basic Neoclassical Growth Model

It is straightforward to generalize the basic neoclassical growth model discussed above to allow for population growth and ongoing technical change. We have abstracted from these forces because our focus in this course is on short-run fluctuations. However, once the model has been adapted in the ways described below, it can also be used to think about issues of long-run growth.



Did u know? Productivity of physical capital which is measured by profit, remains constant in the long run.

5.5 The Solow Model

Assumptions of the Solow Model

1. The simplifying assumption of the model is that the economy produces one composite good which can either be consumed or accumulated as a stock of capital. No denial to the fact that many goods are produced in the economy but only for simplicity sake, it has been assumed that one composite or aggregate good is produced.
2. All labour is assumed to be homogeneous.
3. Stock which is accumulated in the past (referred to as capital) and labour are the factors of production in the production function.
4. Constant returns to scale are assumed to prevail, i.e. any given percentage change in inputs brings forth equal increase in output.
5. MPS is constant. And Savings = sY , where s is MPC.
6. Labour force is increasing at a growth rate which is exogenously determined.
7. It is a closed economy.
8. It is a laissez faire economy with no interference of the government.

Structure of the Model

Aggregate output function is given by :

$$Y = F(K, L)$$

We have assumed constant returns to scale, then if K and L are increased by a ,

$$\therefore Y = F[aK, aL] \text{ for } a > 1$$

Then,

$$\frac{Y}{L} = F\left[\frac{K}{L}, \frac{L}{L}\right]$$

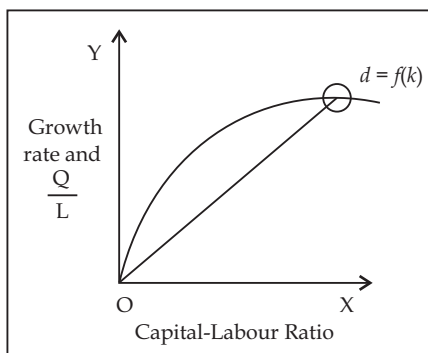
$$\frac{Y}{L} = F\left[\frac{K}{L}, 1\right]$$

If $\frac{Y}{L}$ is denoted by y and $\frac{K}{L}$ by k then

$$y = f(k, 1)$$

$$y = f(k)$$

The above relationship can also be depicted graphically.



Notes

The slope of the curve is $OD = \frac{Q/L}{K/L} = \frac{Q}{K}$

This is capital output ratio denoted by.

Equilibrium Growth

$K = K/L$ Using logarithms

$$\ln(k) = \ln\left(\frac{K}{L}\right)$$

$$\ln k = \ln \frac{K}{L}$$

or $\ln k = \ln k - \ln L$

Differentiating the eqn. w.r.t. time

$$\frac{d}{dt} (\ln k) = \frac{d}{dt} (\ln k) - \frac{dl}{dt} \cdot \frac{1}{L} (\ln L)$$

$$\frac{dk}{dt} \cdot \frac{1}{k} = \frac{dk}{dt} \cdot \frac{1}{k} - \frac{dl}{dt} \cdot \frac{1}{L} (\ln L)$$

or $k = K-L$

...(2)

$$\left[\frac{dk}{dt} = \text{Investment} \right]$$

At Equilibrium Level

Savings = Investment

$$s = sy$$

$$l = \frac{dk}{dt}$$

$$\therefore \frac{dk}{dt} = sy$$

The second term in eqn. (2) on R.H.S shows the proportional growth rate of labour. If we denote it by n then,

$$\hat{k} = \frac{sY}{K} - n$$

Dividing Q and k by L , we get

$$K = \frac{sf(k)}{k} - n \quad \dots(A)$$

Equation A is fundamental equation of the Solow Model

When $\hat{k} = 0$, then there is equation in the economy

Notes

$$\dot{k} = \frac{sf(k^*)}{k^*} - n$$

Putting

$$K = 0$$

$$0 = \frac{sf(k^*)}{k^*} - n$$

$$\frac{sf(k^*)}{k^*} = n$$

Where an $*$ above k denotes its equilibrium value. Which is here

$$\frac{dk}{dt} \cdot \frac{1}{k} = 0$$

or

$$\frac{dk}{dt} = 0$$

The equilibrium q value is obtained as:

$$q^* = f(k^*) = \frac{nk^*}{s}$$

or

$$sq(k^*) = NK^*$$

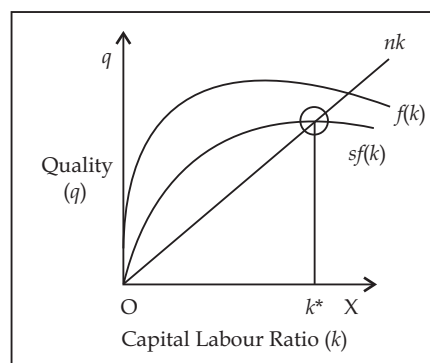
It is shown with the help of following diagram.

At any point to the left of k^*

$$\frac{sf(k)}{k} > n$$

and at any point to the right of k^*

$$\frac{sf(k)}{k} < n$$



Hence, the equilibrium condition in the Solow Model are

$$\frac{f(q)}{Q} = \frac{q}{Q} = \frac{Q/L}{K/L} \cdot \frac{Q}{K} = \frac{1}{V^*}$$

where V is capital-output ratio

Consumption in the Solow Model

In a two sector economy, National income is in equilibrium

where

$$AD = AS$$

$$C + I = Y$$

(1)

Where

Y = National Income

C = Consumption

I = Investment

Dividing both sides by L

$$\frac{Y}{L} = \frac{C}{L} + \frac{1}{L}$$

Notes

It is explained before that $\frac{Y}{L} = y = f(k)$

So $f(k) = \frac{C}{L} + \frac{1}{L}$

Since we are assuming

$$K = I$$

Where

K = Net investment

I = Gross Investment

i.e. Depreciation = 0

$$\therefore \frac{Y}{L} = \frac{C}{L} + \frac{K}{L} \quad \dots(1)$$

Let us assume $k = \frac{K}{L}$ where k is capital-labour ratio

$$\Rightarrow \frac{dk}{dt} \cdot \frac{1}{k} = \frac{dk}{dt} \cdot \frac{1}{k} - \frac{dl}{dt} \cdot \frac{1}{L}$$

$$\text{or} \quad \hat{k} = \hat{k} - L$$

when $\wedge$ denotes proportional growth rate.

Dividing both sides by L

$$\frac{\hat{K}}{L} = \frac{\hat{K}}{L} - \frac{\hat{L}}{L}$$

$$\frac{K}{L} = k + nk$$

...(2)

Putting equations (2) in (1)

$$\therefore F(k) = \frac{C}{L} + k + nk$$

Self-Assessment

1. Fill in the blanks

- All labour is assumed to be
- Constant returns to scale are assumed to prevail, any given percentage change in brings forth equal increase in output.
- In Harrod domar model capital output ratio is an variable.
- In solow model there is along that capital output ratio can take.
- The simplifying assumption of the model is that the economy produces one good which can either be consumed or accumulated as a stock of capital.

Notes

5.6 Some Applications of the Neo-classical Model*Depreciation of Capital Stock*

If there is no depreciation at all,

Gross Investment = Net Investment

or $I = K$

If capital depreciates at say

a%, we can say

$$I = K + aK$$

where I = Gross Investment

k = Net Investment

a = Rate of depreciation

Dividing both sides by L , we get

$$\frac{I}{L} = \frac{K}{L} + \frac{ak}{L}$$

$$\frac{I}{L} = \frac{K}{L}(1+a)$$

(2)

We know that

$$\frac{K}{L} = k + nk. \text{ (divided in the structure of Solow Model)}$$

Substituting this equation (2)

$$\frac{I}{L} = k + nk + ak$$

$$\frac{I}{L} = k + (n+a)k$$

...(3)

Since in equilibrium,

$$S = I$$

$\frac{I}{L}$ can be written as $\frac{S}{L}$ which is denoted as $sf(k)$

∴ Putting these values in equation (3), we get

$$sf(k) = k + (n+a)k$$

$$\text{or } k = \frac{sf(k)}{k} - (n+a)k$$

$$\text{or } \frac{k = sf(k)}{k} - (n+a)$$

This is equation for depreciation of capital stock. Actually, it is only the modification of fundamental equation of the Solow Model.

Variable Savings Rate

Solow Model does not assume saving rate to be constant. In Solow model, as savings increase from s_1 to s_2 , it leads to increase in $sf(k)$ and hence $sf(k)$ curve shifts upward. It causes a newer point of

intersection between $sf(k)$ and nk . At new equilibrium point, k and y both will increase. At higher rates of savings, the economy will have a large capital stock and output. But increase in savings will increase the output per person only temporarily.

Many economists have emphasized that nations should raise their savings to stimulate the rate of economic growth. This is called Solowian Paradox of Thrift. In order to bring a permanent increase in growth rate, we need to work on improvement of technology.

Notes



Notes

Solow's Model is indicating that a permanent change in savings rate i.e. MPC has only temporary effect on the economy's Growth Rate.

Population Growth

Population is an asset as well as a liability. Solowian model is also used to explain the effect of increase in population on growth rate.

If in an economy, population is increasing, at a rate denoted by n , it will increase the number of workers available and hence, capital per worker i.e. k will fall.

We know that

$$\Delta k = sf(k) - nk$$

So, an increase in population (n , the level, not rate) reduces k .

Now if there is change in the rate of population itself, say, population increases from n_0 to n_1 then n_k line will tilt upwards. New equilibrium will be at to the left of previous equilibrium point. This will cause k to fall. As it has been explained earlier, $y = f(k)$, a reduction in k will reduce y as well. Therefore, a developing country must take care that population does not increase too much in order to maintain full employment equilibrium.

Self-Assessment

2. Multiple choice questions:

Choose the correct option.

- (i) $\frac{K = sf(k)}{k} - (n + a)$ is the equation for depreciation of.
 - (a) Capital stock
 - (b) fundamental stock
 - (c) basic stock
 - (d) Free stock
- (ii) is an asset as well as a liability.
 - (a) Economy
 - (b) population
 - (c) equilibrium
 - (d) productivity
- (iii) Many economists have emphasized that nations should raise their savings to stimulate the rate to
 - (a) economic stability
 - (b) economic balance
 - (c) economic growth
 - (d) economic structure

5.7 Money in the Neo-classical Growth Model

The role of money in neoclassical growth model is explained by James Tobin in his paper published in 1965.

He made use of Fisher's Simple Quantity Theory of money Equation $MV = PY$ and made following assumptions:

- (a) Velocity of money is constant.

Notes

- (b) Growth in money = inflation rate – growth in nominal GDP

M = money stock;

Y is growth of output

According to Tobin, if A is real wealth to be held in the form of two assets, real money (M/P), and physical capital (K) M/P is real money balances in such a proportion that

$$A = \alpha (M/P) + (1 - \alpha)K$$

Where $0 < \alpha < 1$

Tobin exclaimed that people make a comparison between R (real rate of return) and Marginal productivity of capital. So, during inflation, people hold less of real money and more of K, opposite will happen during recession.

5.8 Convergence and Poverty Traps

Convergence

Solow Model claims that over a long period of time, all nations of the world would tend to converge towards same rate of growth. It is referred to as convergence.

Following reasons are given for convergence:

- Since rate of return on capital is higher in countries where capital is relatively scarcer, hence, capital will flow from the developed countries to developing and under-developed countries.
- As capital will move from developed countries to developing and under-developed countries, the incomes of poorer countries will also increase.



Notes

Solow model claims that all countries attain balanced growth path in the long run, it would converge.

Types of Convergence

- Absolute Convergence:** It states that if n number of countries have access to same technology, have same saving ratio, same population growth rate but different capital output ratio, then all countries would converge to same level of equilibrium steady growth rate. It is so because capital output ratio will be higher in poor country and hence, capital and output in poor country will grow at a rate faster than the rate of growth of population. While, capital and output in rich country will grow at a rate slower than the rate of growth of population. It implies that the poor country will grow at a faster rate than rich country. The gap between two countries will narrow down.

Empirical evidence has not supported the existence of absolute convergence. So, the concept of conditional convergence came into the picture.

- Conditional Convergence:** Conditional convergence states that if n number of countries has access to same technology, same population growth rate but different saving ratios and capital labour ratio, then there will still be convergence at same growth rate but equilibrium capital-output may or may not be equal. This is so because of paradox of savings which states that a permanent change in savings rate i.e. MPC has only temporary effect on the economy's growth rate. In real life scenario, even conditional convergence is not observed because different countries have different population growth rates.

In order to examine the validity of the unconditional convergence, a well known study was conducted by Baumol, which should have shown inverse relationship between initial per capita level and growth rate of per capita income to prove that conditional convergence actually

operates. But, Baumol found a regression which showed almost perfect convergence.

Baumol's findings were challenged by Bradford De Long on two grounds: (a) Sample selection was biased; (b) there was measurement error in the findings.

Notes

Poverty Traps

A poverty trap is "any self-reinforcing mechanism which causes poverty to persist." If it persists from generation to generation, the trap begins to reinforce itself if steps are not taken to break the cycle.

A mechanism which makes it very difficult for people to escape poverty. A poverty trap is created when an economic system requires a significant amount of various forms of capital in order to earn enough to escape poverty. When individuals lack this capital, they may also find it difficult to acquire it, creating a self-reinforcing cycle of poverty.

In the developing world, many factors can contribute to a poverty trap, including: limited access to credit and capital markets, extreme environmental degradation (which depletes agricultural production potential), corrupt governance, capital flight, poor education systems, disease ecology, lack of public health care, war and poor infrastructure.

Jeffrey Sachs, in his book *The End of Poverty*, discusses the poverty trap and prescribes a set of policy initiatives intended to end the trap. He recommends that aid agencies behave as venture capitalists funding start-up companies. Venture capitalists, once they choose to invest in a venture, do not give only half or a third of the amount they feel the venture needs in order to become profitable; if they did, their money would be wasted. If all goes as planned, the venture will eventually become profitable and the venture capitalist will experience an adequate rate of return on investment. Likewise, Sachs proposes, developed countries cannot give only a fraction of what is needed in aid and expect to reverse the poverty trap in Africa. Just like any other start-up, developing nations absolutely must receive the amount of aid necessary (and promised at the G-8 Summit in 2005) for them to begin to reverse the poverty trap. The problem is that unlike start-ups, which simply go bankrupt if they fail to receive funding, in Africa people continue to die at a high rate due in large part to lack of sufficient aid.

Sachs points out that the extreme poor lack six major kinds of capital: human capital, business capital, infrastructure, natural capital, public institutional capital, and knowledge capital. He then details the poverty trap:

The poor start with a very low level of capital per person, and then find themselves trapped in poverty because the ratio of capital per person actually falls from generation to generation. The amount of capital per person declines when the population is growing faster than capital is being accumulated ... The question for growth in per capita income is whether the net capital accumulation is large enough to keep up with population growth.

Sachs argues that sufficient foreign aid can make up for the lack of capital in poor countries, maintaining that, "If the foreign assistance is substantial enough, and lasts long enough, the capital stock rises sufficiently to lift households above subsistence."

Sachs believes the public sector should focus mainly on investments in human capital (health, education, nutrition), infrastructure (roads, power, water and sanitation, environmental conservation), natural capital (conservation of biodiversity and ecosystems), public institutional capital (a well-run public administration, judicial system, police force), and parts of knowledge capital (scientific research for health, energy, agriculture, climate, ecology). Sachs leaves business capital investments to the private sector, which he claims would more efficiently use funding to develop the profitable enterprises necessary to sustain growth. In this sense, Sachs views public institutions as useful in providing the public goods necessary to begin the Rostovian take-off model, but maintains that private goods are more efficiently produced and distributed by private enterprise. This is a widespread view in neoclassical economics.

Several other forms of poverty trap are discussed in the literature, including nations being landlocked with bad neighbors; a vicious cycle of violent conflict; subsistence traps in which farmers wait for middlemen before they specialize but middlemen wait for a region to specialize first; working capital traps in which petty sellers have inventories too sparse to earn enough money to get a bigger inventory;

Notes

and low skill traps in which workers wait for jobs using special skill but firms wait for workers to get such skills.



What is poverty traps.

Self-Assessment

1. State whether the following statements are 'true' or 'false'.
 - (i) The role of money in neoclassical growth model is explained by James Tobin in his paper published in 1965.
 - (ii) Trbin made use of Fisher's simple quantity theory of money equation $Mv = PX$
 - (iii) Empirical evidence has supported the existence of absolute convergence.
 - (iv) In real life scenario, even conditional convergence is not observed because different countries have same population growth rates.
 - (v) Neo-classical Model assumes that population is a factor which is exogenously determined at a rate denoted by n .

5.9 Summary

- Population is an asset as well as a liability. Solowian model is also used to explain the effect of increase in population on growth rate.
- The role of money in neoclassical growth model is explained by James Tobin in his paper published in 1965.
- Tobin exclaimed that people make a comparison between R (real rate of return) and Marginal productivity of capital. So, during inflation, people hold less of real money and more of K , opposite will happen during recession.
- **Absolute Convergence:** It states that if n number of countries have access to same technology, have same saving ratio, same population growth rate but different capital output ratio, then all countries would converge to same level of equilibrium steady growth rate.
- **Conditional Convergence:** Conditional convergence states that if n number of countries has access to same technology, same population growth rate but different saving ratios and capital labour ratio, then there will still be convergence at same growth rate but equilibrium capital-output may or may not be equal.
- Baumol's findings were challenged by Bradford De Long on two grounds: (a) Sample selection was biased; (b) there was measurement error in the findings.
- Neo-classical model exclaimed that in the long run, all nations of the world would tend to converge towards same rate of growth. But the hypothesis did not hold true in real scenario. This was claimed that poor nations will grow at a higher rate and gradually the gap between nations will disappear. But the poor nations were actually caught up in a situation where they could not come out of the vicious circle of poverty. This is called poverty traps.

5.10 Keywords

- Productivity : The rate at which a worker a company or a country produces goods.
- Capital : A large amount of money that is invested.
- Proportion : The relationship of one thing to another in size, amount etc.
- Consumption : The act of buying and using products.
- Depreciation : The process to become less valuable over a period of time.

5.11 Review Questions

Notes

1. Describe the structure of solow model
2. State and discuss the assumptions of the solow model
3. Compare the solow model with the Harrod Domar Model.
4. Discuss the effect of a change in the savings rate using the solow model.
5. Briefly state how Tobin brings in money in a growth model.

Answers: Self Assessment

1. (i) homogeneous (ii) input (iii) exogenous (iv) range of values
(v) composite
2. (i) (a) (ii) (b) (iii) (c)
3. (i) T (ii) F (iii) T (iv) F
(v) T

5.12 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

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Unit 6: Economic Growth Models-II: Growth and Distribution

CONTENTS

Objectives

Introduction

- 6.1 John Robinson's Model of Economic growth and Capital Accumulation.
- 6.2 Kalecki's theory of Distribution Under Monopolistic capitalism
- 6.3 Kaldor's Model of Economic Growth
- 6.4 Pasinetti's Theory of Growth and Distribution
- 6.5 Reformulating the Kaldorian Model
- 6.6 Summary
- 6.7 Key-Words
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- 6.9 Further Readings

Objectives

After reading this unit students will be able to:

- Know about Joan Robinson's Model of economic growth and capital accumulation.
- Describe Kalecki's theory of Distribution under monopolistic capitalism.
- Explain Kaldor's model of economic growth.
- Understand Pasinetti's theory of growth and distribution.
- Learn about reformulating the Kaldorian model.

Introduction

The theories of economic growth that were developed after Keynes are known as Modern Theories of Growth and Development. Broadly, there are three branches of Modern Theory. First is Harrod-Domar model that was discussed in chapter two. The other is neo-classical model of economic growth explained in chapter three. This chapter explains the third branch of modern growth theory given by Joan Robinson and Nicholas Kaldor of Cambridge University and hence is also called Cambridge Theory. This theory is extremely critical of Neo-Classical theory. It criticizes classical approach to savings and investments. It also criticizes production function and marginal productivity theory of income distribution. Cambridge school gives both a theory of income distribution and economic growth.

6.1 Joan Robinson's Model of Economic Growth and Capital Accumulation

This theory was provided by Mrs. Joan Robinson in 1956 in her book 'The Accumulation of Capital'.

Assumptions

1. There is no foreign trade or it is a three sector economy.
2. There is laissez faire competition in the market.

3. There are two factors of production; labour and capital.
4. Technology remains unchanged.
5. Production function is given and fixed.
6. Labour is abundant.
7. National product is divided between entrepreneurs (owners of capital) and workers (owners of labour).
8. General Price level remains unchanged.
9. Saving-investment function is performed by entrepreneurs and workers are spending their entire income in consumption.

The Model

The formal version of the verbal model of Mrs. Joan Robinson has been given by Prof. K K Kurihara. According to him, since we assumed that there are two factors of production; labour and capital; and hence National product is divided between entrepreneurs (owners of capital) and workers (owners of labour) in the form of wage bill and profits, the distribution of income is represented in the following way:

$$pY = wN + \pi pK$$

Where,

p = Average price of output

Y = Net National Product

w = Nominal Wage rate

N = Workers employed rate

π = Gross Profit rate (Inclusive of interest)

K = Amount of Capital Stock

On re-arranging the above equation, we get-

$$\pi pK = pY - wn$$

$$\pi K = Y - wpN$$

$$\pi = Y/K - w/p \cdot K/N$$

$$\pi = \frac{Y/N - w/p}{K/N}$$

$$\pi = \frac{p - w/p}{Q}$$

Where $p = Y/N$ is labour productivity and $Q = K/N$, capital-labour ratio.

The equation above shows that profit rate is a positive function of labour productivity, and a negative function of wage rate (w/p) and capital labour ratio (K/N).

Thus, in order to increase the profits either we must increase labour productivity or decrease wage rate (w/p) and capital labour ratio (K/N).

Mrs. Joan Robinson's growth model proves the circular relationship between the rate of accumulation of capital and rate of profit. This is done by incorporating Keynesian theory of income and employment.

According to Keynesian identity

$$Y = C + I$$

Notes

And $S = I$
 Where, $C = \text{Consumption,}$
 $S = \text{Savings and}$
 $I = \text{Investment}$

Mrs. Joan Robinson's growth model is based on the assumption that saving-investment function is performed by entrepreneurs and workers are spending their entire income in consumption. Therefore,

$$S = \Delta K = I$$

$$I = \Delta K$$

So, $\Delta K = \Pi K$

$$\Delta K/K = \Pi$$

Or $\Pi = \frac{p - w/p}{Q} = \Delta K/K$

This equilibrium indicates that the rate of profit is positively dependent on the rate of accumulation going on. On the other hand, rate of accumulation is also positively dependent on the rate of profit. Hence, it becomes a circular relation in which one reinforces the other.

The Golden Age

Golden Age Equilibrium refers to a situation in which smooth steady growth at full employment level arises out of the equality of the 'Desirable' and 'possible' rates of accumulation.

Suppose capital labour ratio (K/N or Q) is constant at full employment level, then

$$K/N = Q$$

$$K = QN$$

Therefore, $\Delta K = \Delta NQ$

$$\Delta N = \Delta K/Q$$

Dividing both sides by N

$$\Delta N/N = \Delta K/Q/N$$

$$= \Delta K / Q / K/Q$$

(because $Q = K/N$)

$$\Delta N/N = \Delta K/K$$

Rate of change in labour is equal to rate of change in capital or at full employment level with constant Q ; labour and capital grow at the same rate.

This is called Golden Age because there is harmony on all sides.

Stability of 'Golden Age' Equilibrium

Disequilibrium means either:

(a) $\Delta N/N > \Delta K/K$ or

(b) $\Delta N/N < \Delta K/K$

(a) When $\Delta N/N > \Delta K/K$, the rate of growth of labour is more than the rate of accumulation then there will be surplus labour in the economy. It will create a situation of unemployment. If the price level remains same, real wage rate will fall. It is proved earlier that with the fall in wage

Notes

rate, the rate of capital accumulation goes up. With increase in the rate of capital accumulation, equilibrium will get established once again. However, it will happen only if money wage rates are flexible.

- (b) When $\Delta N/N < \Delta K/K$, the rate of growth of labour is less than the rate of accumulation then there will be deficiency of labour in the economy. It will create a situation of excess capital accumulation. If the price level remains same, real wage rate will rise. Changes in capital labour ratio and the productivity of labour would also help in restoring equilibrium level.

Limping Golden Age: It is a situation in which the steady rate of capital accumulation is happening but there is unemployment of labour with it. On the contrary, if rise in level of employment is more than the rate of increase in population, the limp would get mild.

Leaden Age: It is a special case of limping golden age in which unemployment is not increasing because of increase in population but lack of accumulation of capital.

Restrained Golden Age: It is an age in which there is full employment of resources but the 'desired rate of accumulation' is more than 'possible rate of accumulation'.

Bastard Golden Age: It is a situation in which unemployment prevails but the real wage rates remain rigid towards downwards. Inflation acts as a barrier in capital accumulation.



Did u know? The intensity of the limp may be different in different situations. When rise in level of employment is less than the rate of increase in population, the limp would get worsened.

Criticism

Some loopholes of the model are as follows:

- Wage rates are not as flexible as assumed in the model. The assumption that rate of capital accumulation gets adjusted according to the level of population growth by making changes in wage rate, profit rate and labour productivity but it does not happen so easily. It can better be achieved by making use of fiscal and monetary measures.
- The model neglects the role of state and thereby the role of monetary and fiscal tools in determining growth rate. State plays an important role in ensuring steady growth rates.
- Assumption of a given and constant technique is unrealistic. When there will be increased pressure on labour supply there will be inducements to introducing labour saving technologies.
- It does not consider socio-cultural-institutional factors in economic growth.



Notes The inter-connecting straits have not been explained in the model. It seems to be an isolated island. The model can not predict the possibility of the coming phases of development.

Self Assessment

- Fill in the blanks
 - According to theory provided Mrs. Joan Robinson there is no trade or it is a three sector economy.
 - product is divided between entrepreneurs and workers.
 - Saving-investment function is performed by entrepreneurs and workers are spending their entire income in

Notes

- (iv) The equilibrium indicates that the rate of is positively dependent on the rate of accumulation going on.
- (v) is a situation in which the steady rate of capital accumulation is happening.

6.2 Kalecki's Theory of Distribution under Monopolistic Capitalism

Kalecki was a polished economist who has written the diverse aspects of economics.

Kalecki gave his theory in his essay in 1969 titled 'Introduction to the Theory of Growth in a Socialist Economy'.

Assumptions

1. Short Run Marginal Cost coincides with Short Run Average Cost to a certain point corresponding to practical capacity.
2. Excess capacity does exist in the economy or the economy operates below maximum practical capacity.
3. There is monopoly power in factor as well as commodity market.

The Model

Kalecki theory of distribution is dependent on Learners's measure of degree of monopoly of a single firm

$$M = \frac{P - m}{P}$$

Where, M is degree of monopoly, P is price and m is marginal cost.

Since, Kalecki assumes that $MC = AC$, thereo fore

$$M = \frac{P - a}{P}$$

Or $PM = P - a$

Multiplying both sides by x , we get-

$$xPM = x(P - a)$$

to get gross capitalist's income for the economy, the gross capitalist income of all the firms is added.

$$\sum xPM = \sum x(P - a)$$

$\sum xP$ is equal to total turnover in the economy, thus;

$$T = \sum xP$$

Dividing both sides by T, we get,

$$\sum xPM/T = \sum x(P - a)/T$$

Putting $T = \sum xP$

$$\sum xPM/\sum xP = \sum x(P - a)/T$$

$$M = \sum x(P - a)/T$$

Or Macro Degree of Monopoly = Gross Profits/Aggregate Turnover.

Labour Share and Degree of Monopoly

More is the share of labour in total aggregate output; less will be the degree of monopoly at macro level and *vice-versa*.

It is so because when during boom period competition increases, it will decrease the degree of monopoly. It will increase the share of labour in national income.

Notes

A Critical Appraisal

1. The model is based on unreal assumptions that $MC = AC$.
2. The model ignores the role of other factors affecting distribution of income amongst different factors of production and considers only the shares of profits.
3. Role of trade unions is also ignored.
4. What is golden age?

Self Assessment

2. State whether the following statements are 'true' or 'false'.
 - (i) Kalecki was a polished economist who has written the diverse aspects of economics.
 - (ii) Kalecki gave his theory in his essay in 1969 titled "Introduction to the theory of growth in a socialist economy."
 - (iii) Excess capacity does not exist in the economy or the economy operates below maximum practical capacity.
 - (iv) Macro degree of Monopoly $\neq$ Gross profits/Aggregate turnover.
 - (v) Kalecki theory of distribution is dependent on Learner's measure of degree of monopoly of a single firm.

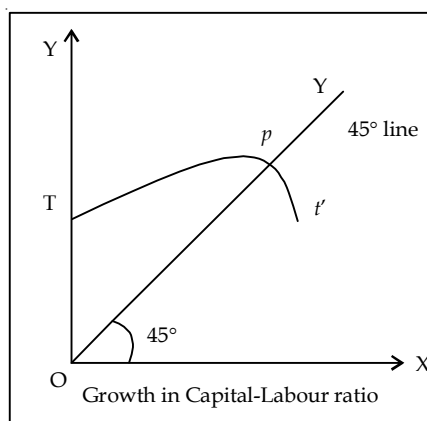
$$M = \frac{P - m}{P}$$

6.3 Kaldor's Model of Economic Growth

Prof. Kaldor provided a model of economic growth in which he related technical progress to capital accumulation. Unlike classical models, in his model technical progress is an endogenous variable.

Assumptions

1. He assumed full employment in the economy and hence AS curve is perfectly inelastic.
2. National Income consists of wages (includes wages as well as salaries) and profits (includes income of entrepreneurs as well as property owners).
3. Both wage earners and profit earners save and hence total savings dependent on wages as well as profits.
4. Profits depend on the level of investment.
5. General price level is constant.
6. Technology keeps changing as per the level of capital accumulation.
7. Kaldor assumes technical progress function which is a joint product of growth of capital and growth of productivity. Therefore, technical progress function is shown by T' in figure below. As shown in the diagram, T' is the technical progress function which is convex upwards but flattens out beyond a certain point such as A when capital per worker starts diminishing.



Notes

Working of the Model

The model can be explained for two situations:

- (a) **When there is constant population growth:** Kadlor has assumed saving function, investment function and technical progress function as follows:

- (i) **Saving Function :** $S_t = aPt + b(Y_t - Pt)$

Where, P_t = Profit in time period t

S_t is saving in time period t

Y_t is income in time period t

a and b are MPSs of profit and wages and lie between 0 and 1.

- (ii) **Investment Function**

$$K_t = a'Y_{t-1} + b'(P_{t-1}/K_{t-1})Y_{t-1}$$

$$\Delta K_t = K_t - K_{t-1}$$

Where K_t is stock of capital in time period t

Y_{t-1} is the output of previous period,

(P_{t-1}/K_{t-1}) is rate of profit on capital

a' and b' are coefficients of output and rate of profit respectively such that a' and b' are greater than 0.

- (iii) **Technical Progress Function**

$$[Y(t-1) - Y_t] / Y_t = a'' + b'' \Delta K_t / K_t$$

where, $Y(t-1) - Y_t$ is rate of growth of income,

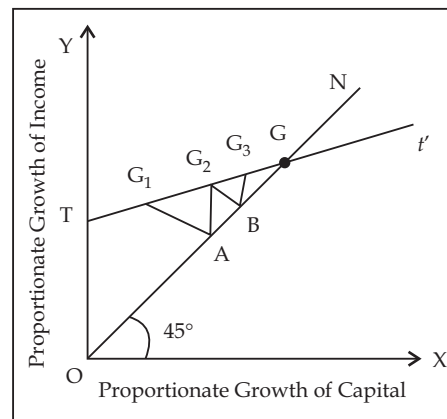
$\Delta K_t / K_t$ is rate of net investment;

a'' is coefficient of technical progress

b'' capital per labour C/L and a'' is greater than one and b'' lie between 0 and 1.

Given these three functions the rate of growth of income can be shown with the help of diagram given on next page. In the diagram, proportionate growth of capital is measured on x -axis and proportionate growth of income is shown on y -axis. The point where technical progress function tt' intersects the 45° line is a point of steady economic growth because at this point proportional growth of capital is equal to proportional growth of national income.

If the economy is operating on any other point, there is a tendency for it to move towards point G. suppose the economy is operating at some point like G_1 , where growth of output is more than growth of capital, it will induce investors to invest more in the subsequent period say equal to G_2 , which in turn will increase output to O_1 and the process will go on until the economy reaches at point G.

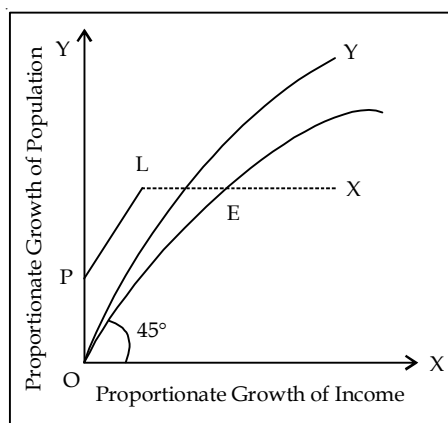


- (b) **When there is Expanding Population:** By dropping the assumption of constant population, Kadlor expressed the relationship between population growth and growth of income algebraically as :

$$\Delta K_t = g_1 (g_1 \geq \lambda)$$

Notes

If $g_t > \lambda$ or to say the rate of increase in population (g_t) is more than rate of increase in income i.e. growth rate (g_t), then rates of population and growth will continue to rise until growth rate of population equals λ .



In the diagram above, proportional growth rate of income is measured on x -axis and proportional growth rate of population is measured on y -axis. OL is the growth path of income. PL is the curve showing growth rate of population. As rate of growth of income grows, rate of growth of population also grows. In the long run, population will increase at its highest rate exhibited by L , in the diagram. It is assumed that technical progress function remains unaffected by changes in population. Let us take a case of a developing country where technical progress function will be lowered due to increase in population as it has a low capacity to absorb technical changes. In this situation, in order to maintain output per head at a constant level, a certain percentage of growth in capital per head is required.

Hence to conclude, growth in population will lead to long run equilibrium growth in income depending upon relative strength of :

- The highest rate at which population can grow.
- The rate of technical progress.

A Critical Appraisal

Appreciations

- Kadlor's model explains the steady path of growth not a steady state i.e. it is dynamic not static.
- The division of the model into two phases: with constant population and with expanding population; makes it extremely useful particularly for developing countries.
- Kadlor's technical progress function relates output per head to capital per head.

Criticism

- This model does not explain the determination of the rate of growth of the economy in terms of the volume of investment, saving-income ratio and capital output ratio.
- It does not explain the reason for the stability or instability of a particular point of equilibrium.

6.4 Pasinetti's Theory of Growth and Distribution

Pasinetti's theory of growth and distribution is a refinement or a corrected reformulation of Kadlor's model. He criticized Kadlor's model for its formulation of existence of only one saving ratio that keeps system in equilibrium for any given rate of population growth and technical progress. In his words, "In any type of society, when any individual saves part of the income, he must also be allowed to own it; otherwise he would not save at all." Accordingly, he divided total profits into two parts one part accrues to the capitalists and other to the workers.

6.5 Reformulating the Kaldorian Model

As given above, he categorised profits into two parts, so:

$$P \equiv P_k + P_w$$

Where, P_k and P_w stand for the respective share of capitalists and workers in the profits.

Therefore, new saving functions are $S_w = S_w (W + P_w)$ and $S_k = S_k \cdot P_k$ and equilibrium condition is

$$I = S_w = S_w (W + P_w) \text{ and } S_k = S_k \cdot P_k$$

From this we can derive the following general equations. These two equations contain all the elements required to correct the post Keynesian theory of income distribution.

$$P/Y = 1/S_k - S_w \cdot I/Y - S_w/S_k - S_w + I$$

$$(S_w S_k / S_k - S_w \cdot K/I - S_w / S_k - S_w \cdot K/Y)$$

$$P/K = 1/S_k - S_w \cdot I/K - S_w / S_k - S_w + Y/K + iK_w / K$$

Rate and Share of Profits in Relation to the Rate of Growth

Pasinetti maintains that in the long run model, rate of interest must be equal to rate of profits. In such a case one can substitute P/K for I , and we get:

$$\frac{P/K (S_k (I - S_w \cdot Y))}{\Delta} = I - S_w \cdot Y/K$$

Hence, the result is that we do not need to make any assumptions about propensities to save of the workers. In the long run, MPS of workers influences the distribution of income between workers and entrepreneurs but does not influence the distribution between profits and wages and the rate of profits.

Fundamental Relation between Profits and Savings

No matter how many categories of economic agents are there, the ratio of profits to savings will always be for all categories.

Implications of the Model

Two conclusions given by the model are:

1. As the model gave conclusion without assuming a constant saving ratio, it has become much wider. The model does not demand to take any hypothesis about saving behaviour of the workers.
2. The relation between capitalists' savings and capital accumulation is based on simplifying and drastic assumption of negligible savings by the workers.

Conditions of Stability

1. Prices are flexible with respect to wages.
2. Full employment investments are carried out.
3. $S_k > 0$.

Notes*Notes*

Pasinetti proved that in the long run profits will be distributed in proportion to the amount of savings that are contributed by workers and entrepreneurs respectively.

Self Assessment

3. Choose the correct option
 - (i) Profits depend on the level of.....
 - (a) investment
 - (b) wages
 - (c) progress
 - (d) employment
 - (ii) General price level is
 - (a) capital
 - (b) constant
 - (c) income
 - (d) progress
 - (iii) In the long run, ... of workers influences the distribution of income between workers and entrepreneurs.
 - (a) BPS
 - (b) MPS
 - (c) DPS
 - (d) NPS

6.6 Summary

- This theory was provided by Mrs. Joan Robinson in 1956 in her book 'The Accumulation of Capital'.
- Mrs. Joan Robinson's growth model is based on the assumption that saving-investment function is performed by entrepreneurs and workers are spending their entire income in consumption.
- **Limping Golden Age:** It is a situation in which the steady rate of capital accumulation is happening but there is unemployment of labour with it.
- Kalecki was a polished economist who has written the diverse aspects of economics.
- Kalecki gave his theory in his essay in 1969 titled 'Introduction to the Theory of Growth in a Socialist Economy'.
- Pasinetti's theory of growth and distribution is a refinement or a corrected reformulation of Kadlor's model.

6.7 Key-Words

- Sector : A part of a particular area
- Investment : The act of investing money in something
- Intrepreneurs : A person who makes money be starting or running business
- Distribution : The system of transporting and delivering goods.
- Accumulation : To gradually increase in number or quality over a period of time.

6.8 Review Questions

1. Explain the concept of Golden Age equilibrium in Joan Robinson's Model.
2. State the main assumption and describe the Kaleckian model of distribution under monopolistic competition.

Notes

3. What are the main criticisms that can be made of Joan's Model?
4. Compare and contrast Koldar Model and Pasinetti model.
5. Give the assumptions of the kaldorian model and give a critical appraisal of the model.

Answers: Self-Assessment

1. (i) foreign (ii) national (iii) consumption (iv) profit
(v) Limping golden age
2. (i) T (ii) T (iii) F (iv) F
(v) T
3. (i) (a) (ii) (b) (iii) (b)

6.9 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 7: Total Factor Productivity and Growth Accounting

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Introduction

- 7.1 Total Factor Productivity
- 7.2 Estimates of the Production Function and Total Factor Productivity
- 7.3 Determinants of Total Factor Productivity
- 7.4 Factors Affecting Total Factor Productivity
- 7.5 Total Factor Productivity and Growth Accounting
- 7.6 Total Factor Productivity Measurement: Different Approaches
- 7.7 Issues and Debates Related to Total Factor Productivity
- 7.8 Summary
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Objectives

After reading this unit students will be able to:

- Know about the total factor productivity and factor affecting total.
- Learn total factor productivity and growth accounting.
- Describe the total factor productivity measurement different approach.
- Understand the issues and debate related to total factor productivity.

Introduction

Productivity and growth are closely related concepts. Productivity refers to the rate at which resources are being utilized. Increase in productivity leads to more efficient utilization of resources and thereby development. Total factor productivity is a concept which is used in many branches of economics. The TFP approach not only analysis the changes in productivity but also enquires into 'whys' of these changes. When we analyse the factors that affect productivity, we get better understanding of the sustainability of growth. With the advancement of technology, increased expenditure on R and D, improvement in quality of labour *via* education and health, TFP has gained popularity and is considered by most of the economist a cause as well as an effect of growth.

7.1 Total Factor Productivity

Students of international trade commonly believe that international trade policies making a country more open to world trade and stimulating human capital accumulation promote a higher standard of living. That is, greater outward orientation increases efficiency in the use of resources, and encourages production specialization in some industries, in accordance with the principle of comparative advantage. The expansion of exports relaxes the foreign exchange constraint and accommodates larger imports of key inputs in the production process. Countries that pursue greater outward orientation, therefore, can experience faster economic growth. Among the external factors that affect growth, improvements in the terms of trade can exogenously increase output as well. In addition, the higher the human capital stock within a country, the better that country is at adopting the newer technology that promotes economic growth.

Notes

The macroeconomic growth literature identifies both factor accumulation and total factor productivity as principal determinants of growth. The relative influence of these broad causal factors provides a large area of research. In this paper, we separate the contribution of the basic inputs in production that directly affect output growth from factors that indirectly influence growth, that is, the factors that change the efficiency of those basic inputs. Put differently, those other factors in fact determine total factor productivity (TFP). We estimate a series of models, using a relatively large dataset, to calculate TFP and to examine a set of external as well as domestic factors that affect TFP.

Most cross-section and panel studies of economic growth put all countries into the same basket to estimate the elasticities of output with respect to capital and labor, or to calculate returns to scale. Those studies presume that all countries in the sample follow the same overall

technology. A cursory examination of the wide disparities in per capita income and growth rates across countries, however, raises serious doubts on such a presumption. Countries that occupy different rungs of the development ladder probably also occupy different rungs of the technological ladder. Geographical and cultural differences can constrain the rate at which countries adopt modern technology. Our paper examines whether countries in different income groups and geographical locations display similar output elasticities with respect to inputs, and/or similar returns to scale.

Expanded versions of the neo-classical growth model importantly assume that human capital directly enters the production function along with labor and physical capital (Mankiw, Romer, and Weil, 1992; Mankiw, 1005, and Miller and Upadhyay, 2000). Earlier attempts generally fail to uncover a significant contribution of human capital to output in large samples of countries, most likely due to severe measurement problems of human capital. In this paper, we calculate TFP employing only physical capital and labor in the production function and consider how human capital, along with variables capturing outward orientation, influences TFP.

Our main findings include the following. For low-income countries, output responds much more to labor than to capital. That is, the output elasticity with respect to labor exceeds that with respect to capital. The total elasticity of output with respect to capital and labor for the low-income countries implies increasing returns to scale. That result, however, reverses itself for the middle- and high-income countries that display decreasing returns to scale. Thus, the returns to scale for different income groups or regions depends on the level of development.

When we classify countries by geographic regions instead, our previous results based on income categories extend only to Africa. African economies exhibit increasing returns to scale, while Asia, Europe, and Latin America show nearly constant returns to scale. That is, returns to scale for Asia, Europe, and Latin America all cluster around 1, indicating that constant returns may adequately approximate all regions except Africa.

We also find that countries in the middle-income group display elasticity characteristics closer to those for high-income countries than for low-income countries. Apart from relatively similar returns to scale estimate, the middle-income countries also possess a labor elasticity of output nearly equal to that for the high-income group. On the other hand, the elasticity of output with respect to capital is the highest in the middle-income countries, followed by low-income and high-income countries. If middle-income countries match high-income countries in the rate of technological progress, but accumulate capital more quickly, then their output should respond more rapidly to both those sources of growth. Our findings support such a story.

We find similar results for African and low-income countries despite the fact that 5 out of 19 countries in Africa do not belong to the low-income group, and 8 out of 22 countries in the low-income category do not belong to the African group.

Our assertion that all countries do not use the same technology also finds support from our estimates of total factor productivity. Our first set of total factor productivity estimates employs a panel-data fixed-effect regression for all countries with no control for regional or income differences. The second and third sets of total factor productivity estimates come from the composite series of TFP that use separate regressions for income groups and for geographic regions. The results differ markedly.

While middle- and high-income countries show small coefficients of variation in total factor productivity, around 7 percent of the mean, the corresponding coefficients for the low-income countries range from 55 percent to 125 percent. Similarly, regional regressions indicate that TFPs in Africa vary widely, up to 140 percent around the mean, whereas for all other regions such variation stays within 8 percent of the mean. Thus, including African and low-income countries with other countries in the world under the assumption that individual country intercepts summarize most of the nonrandom differences may grossly misrepresent reality.

The following section provides details of the production function estimates and a description of our calculated series for total factor productivity. Section 7.3 explains total factor productivity for each country group and geographic location and considers how important external and internal factors may influence the growth of total factor productivity around the world.

7.2 Estimates of the Production Function and Total Factor Productivity

The Production Function

We estimate important parameters of production functions and calculate our series for total factor productivity from the Cobb-Douglas function specification on three sets of data---panel data for all countries, panel data separated by income category (low, middle and high), and panel data on geographic regions (Africa, Asia+, Europe+, and Latin America).

The Cobb-Douglas production function is written as follows:

$$1. \quad Y = A K^{\alpha} L^{\beta}, \quad 0 < \alpha < 1 \text{ and } 0 < \beta < 1,$$

where Y equals real GDP, K equals the total physical capital stock, L equals the number of workers (labor force), and A equals an index of total factor productivity. We allow for the possibility of non-constant returns to scale by not restricting $(\alpha + \beta)$ to equal one.

Dividing equation (1) by the labor force (L) expresses output, and the physical capital stock on a per worker basis. That is,

$$2. \quad y = A k^{\alpha} L^{\alpha+\beta-1},$$

where y equals real GDP per worker, and k equals the per worker stock of physical capital. Those production functions display increasing, constant, or decreasing returns to scale as $\alpha+\beta$ is greater than, equal to, or less than one, respectively.

Rewriting equation (2) in natural logarithms yields the following:

$$3. \quad \ln y = \ln A + \alpha \ln k + (\alpha + \beta - 1) \ln L.$$

Thus, the tests for constant returns to scale involve whether the coefficient of $\ln L$ equals zero.

Including human capital as an input in the production function proves controversial. Mankiw, Romer, and Weil (1992) advocate such an approach on both theoretical and empirical grounds. In a model that is more comparable to our framework because of the use of panel data, however, Islam (1995) finds that human capital does not contribute significantly to explaining output in the Mankiw-Romer-Weil specification. Miller and Upadhyay (2000), however, do find a significant role for human capital in their estimations. In what follows, we include human capital in a second-stage model that studies total factor productivity.

Panel Data and Fixed-Effects Estimation

Our panel data cover the 1960 to 1989 time period (1959 to 1989 for any growth rate) for a sample of 83 countries in the full data set. The Data Appendix, Table A, lists the countries included in our sample. Our panel combines data in five-year blocks as follows: 1960-64, 1965-69, 1970-74, 1975-79, 1980-84, and 1985-89. Usually, data series reflect averages of the information over five years in each block. Our data encompasses 498 observations (83 countries and 6 time blocks). Our estimating equation emerges by adding a random error to equation (3). This error term incorporates the effects of omitted variables. Classical regression analysis assumes that the omitted variables are independent of the included right-hand-side variables and are independently, identically distributed.

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When using panel data, however, we can further classify the omitted variables into three groups -- country-varying and time-invariant, time-varying and country-invariant, and country- and time-varying variables (see Hsiao, 1986 or Greene, 1997). The country-varying time-invariant variables differ across countries, but are constant within a country over time. The time-varying, country-invariant variables, such as technological shocks, differ over time but are constant at a point in time across countries. Finally, country- and time-varying variables differ across both countries and time.

The estimation of equation (3) without consideration of possible country-specific or time-specific effects can generate misleading results for ordinary-least-squares regressions. Problems emerge when either the unobservable country-specific or time-specific variables correlate with the included right-hand-side variables. Two alternative, but related, procedures exist for addressing these problems -- fixed-effect and random-effect models. We restrict our attention to fixed-effect estimation since the random-effects estimation requires that the omitted variables are uncorrelated with the included right-hand-side variables -- an unrealistic assumption in the context of our model.

If the problem omits country-specific variables, we perform the regression after adjusting all variables by subtracting their respective means over time. Since the unobserved country-specific variables and the intercept do not change over time, such an adjustment drops these variables out of the regression equations. On the other hand, if the problem omits time-specific variables that correlate with the included right-hand-side variables, subtracting the mean over countries drops the intercept and the time-specific effects out of the regression. The revised regression equation in each case provides unbiased and consistent estimates.

Finally, when both country- and time-specific effects correlate with the included right-hand-side variables, we adjust for the means over countries and time. We adopt this last approach and consider fixed effects over countries and time. Our problem, however, has few elements in the time dimension. Thus, we directly include the six time-specific dummy variables, one for each period, and only adjust the data to avoid using 83 country dummy variables.

The estimating equation is as follows:

$$4. \quad \ln y = \ln A + \alpha \ln k + (\alpha + \beta - 1) \ln L_t + \sum_{i=1}^6 \theta_i \text{time}_i + \varepsilon$$

where time_i ($i = 1, \dots, 6$) represent the time dummy variables and the variables for each country measure deviations from their country means over time. We then calculate the country-specific fixed effects of intercepts (cint_j) as follows:

$$5. \quad \text{cint}_j = \overline{\ln y_j} - \hat{\alpha} \overline{\ln y_j} - \hat{\delta}_1 \overline{\ln L_j},$$

where " $\overline{}$ " over a variable implies the mean of that variable, " $\hat{}$ " over a parameter means the estimate of that parameter, $\hat{\delta}_1 = (\alpha + \beta - 1)$ in (4), and $j = \{1, 2, 3, \dots\}$ is the index across countries. Note that the time-specific fixed effects appear directly as the respective coefficients of the time dummy variables.

Production Function Estimates: All Countries

The estimate of the Cobb-Douglas function (equation 4) for the full-panel data set yields the following results:

$$6. \quad \ln y = 0.4756 \ln k - 0.0988 \ln L_{it} + \sum_{i=1}^6 \theta_i \text{time}_i + \varepsilon_i.$$

$$\begin{array}{cccc} (18.86) & (-1.32) & & \\ R^2 = .7860 & SEE = .1269 & F(7,407) = 218.26 & N = 498 \end{array}$$

The coefficient of $\ln L$ (i.e., -0.0988), although only significant at the 20-percent level, indicates that the production function exhibits slightly decreasing returns to scale. The coefficient of $\ln k$ assigns a value of 0.4756 to the elasticity of output with respect to the physical capital stock. These two coefficients

combine to generate the implied elasticity of output with respect to the labor force of 0.4256. Thus, after accounting for country- and time-specific effects, the output elasticities with respect to labor and physical capital sum to a value of 0.9012, indicating a slightly decreasing returns to scale.

Our dataset includes observations for 30 years for each country. Each data point, however, averages 5 yearly observations. Thus, we only have a short panel on the time dimension (six 5-year periods for each country), and hence autocorrelation is not of much concern. On the other hand, heterogeneity of countries in the panel along both the income and locational scales can cause the residual terms to be heteroscedastic. Using the Lagrange multiplier test for the Cobb-Douglas function, however, we find that the statistic equals only 0.021 with a high significance level of 0.88. Thus, the test fails to reject the null hypothesis of constant variances across countries.

Production Function Estimates: Income Levels and Geographic Regions

Another way to test for possible differences in technology divides the sample into groups of countries in different ways. We use two methods to create sub-samples for more intensive study. First, we divide our sample into low-, middle-, and high-income countries based on real GDP per worker for two different periods: 1960-64, and 1970s. The categorization based on 1960-64 incomes allows one to study subsequent growth in originally similarly placed economies and convergence during the sample period. Technological differences among income groups for the entire 30-year period, however, can perhaps better discriminate, if we classify countries according to their income levels during the 1970s, the middle of the three decades in our sample. That is especially desirable if rapid growth elevates countries from low- to middle-income or from middle- to the high-income groups over our entire sample period.

The World Bank divides countries into low-, middle-, and high-income groups based on real GDP per capita. Using a number in the range of 2 to 2.5 to measure the ratio of population to labor force, we convert these ranges into ranges based on real GDP per worker. Thus, our classification based on 1960-64 incomes fixes \$3,000 (in constant 1985 international prices) as the threshold GDP per worker between low- and middle-income countries and \$10,000 per worker between middle- and high-income countries. For the classification based on incomes during the 1970s, an analogous exercise leads to \$4,000 and \$13,500 as the respective cutoffs for GDP per worker.

Second, geography provides another important dimension along which to split our sample. Countries in Africa may use a level of technology that significantly differs from that used in Europe. Our regional sub-samples mostly follow continental divisions, except that we include Australia, Canada, New Zealand, and the U.S. in Europe+, and Fiji and Papua New Guinea in Asia+.

In sum, we divide the full-sample into three different subsamples. The first subsample segregates countries based on real GDP per capita - low-, medium-, and high-income -- using 1960-64 data. The second subsample also segregates based on real GDP per capita, but now using 1970s data. The third subsample segregates based on geography - Africa+, Asia+, Europe+, and Latin America. Table 1 reports F-tests of the null-hypothesis that we can pool the data across income groups or geography. Those F-tests clearly reject the null-hypothesis, indicating that the subsample production function estimates differ significantly from each other.

The results for the estimation of the Cobb-Douglas production functions appear in Table 1. Several noteworthy points emerge. Starting with income categories, we find that the elasticity of output with respect to capital in high-income countries falls substantially below that in other countries. This elasticity equals 0.17 for high-income countries when grouped by incomes for 1960-64, and rises to 0.31 for the same subset when we reclassify countries according to the 1970s' incomes. That increase traces to the movement of Japan and Ireland from the middle- to high-income group. We also find significantly decreasing returns to scale for high-income countries, as the output elasticities with respect to capital and labor sum to only about 0.5.

Second, we find a close similarity of results for middle- and low-income groups across our two income classifications. In particular, the middle-income group fairly well represents the entire sample in terms of key results. The returns to scale for the middle-income countries matches closely that for the

Notes

whole set of countries. The combined elasticity of output with respect to capital and labor equals 0.82 for the middle-income group and equals 0.91 for all 83 countries. That comparability of the middle-income group with the world as a whole reflects a higher output elasticity with respect to capital (0.57 versus 0.48 for the entire sample) largely offset by a lower elasticity with respect to labor (0.25 versus 0.43).

The similarity of results, however, does not carry through to countries on either side of the income scale. Although the capital elasticity of output does not change that much (0.46 versus 0.48), the labor elasticity of output is much higher for the low-income countries (1.34 versus 0.43). Those values indicate that the production function exhibits significantly increasing returns to scale for low-income countries in sharp contrast, as discussed above, to the decreasing returns to scale for the high-income subset. That result, therefore, highlights the potential for convergence in income per worker between rich and poor countries. Focusing on our division of countries into income groups based on incomes for 1960-64, if low-income countries, on average, experience increasing returns to scale in production during the next 25-30 years, we expect incomes to converge and a number of countries in the sample possibly to move up the income distribution.

Another way to explore for possible differences in technology separates countries into geographic regions (Frankel and Romer, 1999). The findings for our four regions show significant similarity in key parameters, except for Africa. The scale elasticity for Asia, Europe, and Latin America lies between 0.95 (Europe) and 1.08 (Latin America) whereas the elasticity for Africa equals 1.70, and closely follows the elasticity of 1.80 for low-income countries in our earlier analysis. The elasticities of output with respect to capital alone are, however, more comparable for all groups since they range between 0.37 for Asia and 0.54 for Europe with the intermediate values assumed of 0.45 for Africa and 0.51 for Latin America.

In sum, we find evidence of increasing returns to scale for low-income and African countries, although these two sub-samples do not exactly overlap. Several Asian and Latin American countries appear in the low-income category, and several African countries appear in the middle-income category. Middle- and high-income countries display decreasing returns to scale whereas countries from Asia, Europe, and Latin America indicate a scale elasticity close to unity, ranging from slightly decreasing (0.95) for Europe to slightly increasing (1.08) for Latin America. Thus, we do find evidence of technological differences across groups of countries despite the fact that we limit our attention to a single Cobb-Douglas specification of the production function.

As a final check, we calculate the correlation coefficient between the series for total factor productivity based on the pooled regression for the entire sample and the combined series for total factor productivity based on the separate estimates for income groups. The rank correlation coefficient between these two estimates of total factor productivity equals 0.74, which is far from perfect but not so low as to suggest no relationship.

The findings from our sub-sample Cobb-Douglas production function regressions for the income and geographic groups raises at least two important questions that deserve further discussion. First, if low-income and African countries exhibit increasing returns to scale, then why do we not observe the convergence of real GDP per capita? Several points relate to this question. The low-income and African countries did not experience the growth in their capital stocks that other country groups experienced. For example, capital stock per worker rose annually during 1960-64 - 1985-89 by only 2.6 percent per year (25 years) for Africa as compared to 2.9 percent for Latin America, 3.8 percent for Europe, and 4.3 percent for Asia. The slower growth rate is all the more unfortunate because of the small capital base that they started with in 1960. Thus, lack of convergence significantly relates to lack of capital accumulation along the production frontier. If low-income and African economies could accumulate capital faster, then the convergence process could start. In the 1990s, although not addressed in our paper, non-convergence between Africa and rest of the world was even more striking due to civil wars, lack of institution building, and limited foreign direct investment in many countries of our sample. In other words, we argue that the lack of growth of factors of production helped to retard progress in the low-income and African countries.

The negative movement in total factor productivity in many low-income and African countries for most periods also provided an important further drag on growth and convergence. On average, total factor productivity decreased monotonically over our sample period for low-income and African countries. Further, the previously mentioned propensity for civil wars and lack of institution building probably plays a dramatic role in total factor productivity movements. Thus, the slow growth of capital in Africa and negative total factor productivity movements did not allow those countries to exploit higher returns to scale in production and to induce convergence of per capita income.

Second, given that high-income countries exhibit decreasing returns to scale, how did those countries continue to increase real GDP per capita? Here, the conventional wisdom holds that the growth in total factor productivity provides a most important contribution to economic growth (e.g., Islam, 1995; Hall and Jones, 1999; Easterly and Levine, 2001). But, Young (1994) offers a contrarian view that factor accumulation and not total factor productivity growth explained economic growth in East-Asian countries.

7.3 Determinants of Total Factor Productivity

The basic characteristics of the different total factor productivity estimates from our model in the last section appear in Table 2. We find that for the low-income group, the mean of the natural logarithm of TFP per worker is negative and the coefficients of variation show a high degree of dispersion. In the regional classification, Africa displays similar characteristics, with a negative mean and high dispersion in the natural logarithm of TFP. For the middle- and high-income countries and those outside Africa, the natural logarithm of TFPs more closely cluster around their respective means.

The Basic Equation

In this section, we examine the role of both domestic and external variables in influencing total factor productivity. Our estimate proceeds with the following equation for total factor productivity:

$$7. \quad \ln tfp = a_1 + a_2 \ln H + a_3 \ln open + a_4 \ln tot + a_5 \ln pd + a_6 \ln (1+?)$$

$$+ a_7 \ln \sigma_x + a_8 \ln \sigma_{tot} + a_9 \ln \sigma_{pd} + a_{10} \ln \sigma_{\pi} + a_{10} + in \Rightarrow \sum_{i=1}^6 a_{10+i} time_i + \varepsilon,$$

where open equals the ratio of exports to GDP or total trade to GDP, tot equals the terms of trade, pd equals local price deviation from purchasing power parity, π equals the inflation rate, and σ_i equals the standard deviation of i ($= x, tot, pd, \text{ and } ?$) over the five-year sub-periods.

Once again, we estimate equation (7) using the fixed-effects method.

Our main goal in this section considers how variables representing the performance of the external sector relate to total factor productivity, and how our results for countries in different income and locational groups compare with the results for the entire sample. The results of our estimates of equation (7) for the pooled sample and for countries at different levels of development based on the 1960-64 average incomes. The values for the TFP variable come from the Cobb-Douglas production function discussed in the last section. Starting with the external sector of the economy, the variables related to trade show a generally positive effect on total factor productivity. Openness exhibits a significant positive effect generally at the 1-percent level for all samples. Greater openness enhances growth of the economy through a larger total factor productivity.

The local price deviation from purchasing power parity displays a significant negative effect at the 5-percent level in the full sample. Here, larger deviations from purchasing power parity associate with lower total factor productivity. To the extent that local deviations from purchasing power parity imply a more-restricted, less-open domestic economy, the coefficient on this variable captures another aspect of the openness of the economy to trade, reinforcing our finding on the export-GDP ratio. The price deviation variable, however, loses its statistical significance in income sub-samples and only retains its negative sign for the middle-income group.

The terms of trade possesses the expected positive effect in the full sample, but is only significant at the 20-percent level. So improvements in the terms of trade weakly associate with higher total factor productivity. Once again, however, this result seems driven solely by countries in the middle-income range. For other groups, the coefficients exhibit a statistically insignificant negative sign, even at the 20-percent level.

Notes

For the domestic variables, human capital exerts an insignificant, albeit positive, effect on TFP while inflation exerts a significant negative effect at the 1-percent level. Human capital turns significant for the middle-income group alone, and that too at the 10-percent level. We get greater consistency for the inflation effect, as most income classifications indicate a highly significant negative effects of inflation on total factor productivity. For the high-income countries, however, it loses its statistical significance and reverses sign. On average, the inflation rate for the high-income group falls well below the 20 percent or so beyond which, according to some studies, inflation begins impinging on growth (Bruno and Easterly, 1998 and Gylfason and Herbertsson, 2001). That finding that higher inflation associates with lower total factor productivity may explain the observed empirical regularity between higher inflation and lower economic growth. That is, higher inflation leads to lower economic growth through its effect on total factor productivity.

The volatility variables (as measured by standard deviations) have, on average, much less significance in explaining total factor productivity. The one exception, the standard deviation of exports to GDP, exhibits a significant negative effect at the 1-percent level. That is, lower export instability associates with higher total factor productivity. This is true of the overall sample and of the low-, middle-, and high-income countries, although the coefficients are much less significant or insignificant for low-income countries. For the low-income group, the volatility coefficients are unexpectedly positive and statistically significant.

In sum, higher and more stable openness and a lower inflation rate associate with higher total factor productivity. The results for the whole sample do not in general extend to component income groups. In particular, the price deviation from purchasing power parity and the terms of trade do not behave in a predictable fashion across country classifications. This suggests that lumping countries at various levels of development together in an empirical growth study may not succeed in uncovering important policy implications.

Human Capital-Openness Interaction

Human capital effects do not emerge in our simple specification of the determinants of total factor productivity. Human capital may affect total factor productivity through its interaction with trade orientation. Greater openness fosters competition, encourages the use of modern technology, increases the demand for high-skilled labor, and promotes learning by doing.

Countries Grouped by Income

Columns 2, 4, 6 and 8 in Table 3 add the interaction term between the human capital and openness variables. We find that markedly different results between two identical TFP regressions but for different TFP series---one estimated using a production function for the entire sample of countries as in Miller and Upadhyay (2000, p.416) and the other based on a production function for each subsample as explained in the last section.

Human capital now exerts a significantly positive direct effect on total factor productivity at 10 percent level for middle- and high-income countries and a significantly negative direct effect for the low-income countries. In another major change, openness exhibits a significant negative effect on total factor productivity in low-income countries. Only the interaction term's coefficient is both positive and significant at the 1 percent level, indicating that low-income economies benefit from a concerted growth of human capital and openness but not necessarily from the development of one or the other in isolation. For middle-income countries, the direct effects of openness and human capital are positive but openness fails to interact with human capital to exert a positive influence on total factor productivity. For high-income countries, the direct effects of openness and human capital are positive and now openness interacts with human capital to reduce total factor productivity.

Other factors including the terms of trade, local price deviation, and domestic inflation do not discernibly change in the way they affect total factor productivity in the specification that includes the interaction term.

The findings for total factor productivity regressions classified by income during the 1970s yield no remarkable differences in results from those for countries grouped by 1960-64 income.

Table 1: Production Function Estimates by Income Level and Region (Cobb-Douglas)**Notes**

	Coef. of $\ln k$	Coef. of $\ln L$	RTS	2R
All Countries	0.4756* (18.86)	-0.0988†† (-1.32)	0.912: DRS	0.786
Countries Grouped by 1960-64 Income Per Worker: F(16, 391) = 9.45*				
High-Income	0.1683** (2.30)	-0.5114* (-5.43)	0.489: DRS	0.816
Middle-Income	0.5694* (12.72)	-0.1719†† (-1.49)	0.822: DRS	0.827
Low-Income	0.4604* (13.68)	0.7953* (3.62)	1.795: IRS	0.779
Countries Grouped by 1970s Income Per Worker: F(16, 391) = 4.52*				
High-Income	0.3096* (5.14)	-0.4824* (-5.12)	0.518: DRS	0.839
Middle-Income	0.6068* (13.48)	-0.1785†† (-1.45)	0.821: DRS	0.830
Low-Income	0.4309* (12.56)	0.6548 (3.01)	1.655: IRS	0.748
Countries Grouped by Geographic Region: F(24, 383) = 11.66*				
Africa	0.4452* (12.06)	0.7041* (2.52)	1.7041: IRS	0.763
Asia+	0.3657* (5.70)	0.0124 (0.05)	1.0124: IRS	0.783
Europe+	0.5408* (8.43)	-0.0486 (-0.33)	0.951: DRS	0.908
Latin America	0.5112* (7.93)	0.0807 (0.54)	1.081: IRS	0.916

Note: All regressions employ the fixed-effect technique for countries. The regressions explicitly include 6 time dummies to capture the fixed effects over time (not reported here). RTS indicates the returns to scale (constant, increasing, or decreasing). $\bar{R}^2$ equals the adjusted coefficient of determination. The F-test considers the null-hypothesis that each subgrouping possesses the same production function.

* means significant at the 1-percent level.

** means significant at the 5-percent level.

† means significant at the 10-percent level.

†† means significant at the 20-percent level.

Notes

Table 2: Basic Statistics on Real GDP Per Worker and TFP Per Worker by Country Groups

Logarithm of Real GDP Per Worker				Logarithm of TFP Per Worker			
Countries Grouped by 1960-64 Income				Countries Grouped by 1960-64 Income			
	Mean	Std. Dev.	Coef.Var.		Mean	Std. Dev.	Coef.Var.
Low	7.662	0.522	6.809	Low	-2.182	1.212	55.550
Middle	8.948	0.427	4.769	Middle	5.223	0.369	7.062
High	9.934	0.279	2.812	High	12.578	0.822	6.532
All	8.880	0.939	10.570	All: Separatea	5.298	5.497	103.743
All: Pooledb	5.536	0.434	7.840				

Countries Grouped by 1970s Income				Countries Grouped by 1970s Income			
	Mean	Std. Dev.	Coef.Var.		Mean	Std. Dev.	Coef.Var.
Low	7.645	0.482	6.303	Low	-0.789	0.988	125.183
Middle	8.928	0.406	4.545	Middle	4.946	0.369	7.454
High	9.899	0.310	3.135	High	10.882	0.778	7.145
All	8.880	0.939	10.570	All: Separatea	5.214	4.449	85.340
All: Pooledb	5.536	0.434	7.840				

Countries Grouped by Geographic Region				Countries Grouped by Geographic Region			
	Mean	Std. Dev.	Coef.Var.		Mean	Std. Dev.	Coef.Var.
Africa	7.826	0.756	9.661	Africa	-0.630	0.880	139.727
Asia+	8.692	0.711	8.180	Asia+	5.509	0.441	7.997
Europe+	9.732	0.506	5.198	Europe+	4.702	0.221	4.700
L. Amer.	8.969	0.578	6.448	L. Amer.	3.889	0.229	5.891
All	8.880	0.939	10.570	All: Separatea	3.431	2.336	68.079
All: Pooledb	5.536	0.434	7.840				

a Results for all countries are combined after performing regressions separately.

b Results for all countries are from the single pooled regression.

7.4 Factors Affecting Total Factor Productivity

In economics, total-factor productivity (TFP), also called multi-factor productivity, is a variable which accounts for effects in total output not caused by traditionally measured inputs. If all inputs are accounted for, then total factor productivity (TFP) can be taken as a measure of an economy's long-term technological change or technological dynamism. TFP cannot be measured directly. Instead it is a residual, often called the Solow residual, which accounts for effects in total output not caused by inputs.

The equation below (in Cobb-Douglas form) represents total output (Y) as a function of total-factor productivity (A), capital input (K), labor input (L), and the two inputs' respective shares of output (?)

Notes

and α are the capital input share of contribution for K and L respectively). An increase in either A, K or L will lead to an increase in output. While capital and labor input are tangible, total-factor productivity appears to be more intangible as it can range from technology to knowledge of worker (human capital).

Technology Growth and Efficiency are regarded as two of the biggest sub-sections of Total Factor Productivity, the former possessing "special" inherent features such as positive externalities and non-rivalness which enhance its position as a driver of economic growth.

Total Factor Productivity is often seen as the real driver of growth within an economy and studies reveal that whilst labour and investment are important contributors, Total Factor Productivity may account for up to 60% of growth within economies.

It has been shown that there is a historical correlation between TFP and energy conversion efficiency.

These are the factors that affect total factor productivity:

Technological Progress:

With technological progress, the inputs (R&D) are utilised 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.



Notes

Hence, in nutshell, the only gateway to long term steady growth is total factor productivity.

Self Assessment

1. Fill in the blanks

- (i) and are closely relates concepts.
- (ii) refers to the rate at which resources are being utilized.
- (iii) is increase in output over a period of tie.
- (iv) An increase in increases total factor productivity and promotes efficiency of the economy.
- (v) Improvement in the number if skilled and trained work force total factor productivity.

7.5 Total Factor Productivity and Growth Accounting

Productivity and growth

- (a) The main reason for some countries performing better than others is difference in their relative productivities.
- (b) More productive nations can produce high quality goods at low cost. It makes them more competitive in world market.
- (c) High productivity brings about higher standards of living.

Hence, there is a strong logic to believe that total factor productivity is the main cause of economic growth. Growth accounting is one such framework that enables us to obtain different perspectives on growth and conduct such an analysis. By referring to Cobb-Douglas production function, we can prove that any change in output is the result of either change in capital stock (K_t) or change in labour force (L_t) or total factor productivity (A_t).

$$Y_t = A_t \cdot K_t^{1/4} \cdot L_t^{3/4} \text{ On taking logs, } \ln Y = \ln A + .25 \ln K + .75 \ln L$$

This equation can also be used to estimate increase in labour productivity i.e. Y/L . This can be written as :

$$Y/L = A(K/L)^{1/4}$$

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

$$\ln Y/L = \ln A + .25 \ln K/L$$

Let us now analyse the effect of change in each component.

Changes in Capital: When capital is raised by α , the proportional growth rate of a quantity raised will be equal to :

$$\ln Y = \alpha \ln K$$

Therefore, if α is .75 then a 5% increase in capital stock will increase output by:

$$\ln Y = .75 \ln K = .75 * 5\% = 3.75\%$$

Changes in Labour: When labour is raised by β , the proportional growth rate of a quantity raised will be equal to:

$$\ln Y = \beta \ln L$$

Therefore, if β is 0.25 then a 1% increase in labour force will increase output by

$$\ln Y = 0.25 \ln L = 0.25 * 1\% = 0.25\%$$

Changes in Total Factor Productivity: In Cobb-Douglas production function, a proportional increase in total factor productivity produces the same proportional increase in output.

$$\ln Y = \ln A$$

Hence, if proportional increase in TFP 4% then output will also increase by 4% labour and capital stock remaining unchanged.

Putting Together

If all the three factors change simultaneously, capital stock, labour stock and total productivity factor then proportional change in output will be given by:

$$\ln Y = \ln A + \alpha \ln K + \beta \ln L \text{ where } \alpha \text{ and } \beta \text{ coefficients of } K \text{ and } L; \text{ and } \alpha + \beta = 1.$$

Growth accounting equation can be broken into components that can be attributed to the observable factors of the growth of capital the labour force and total factor productivity.

Total factor productivity is called the Solow residual or measure of ignorance. It is that portion of growth which is left unaccounted for by increase in factors of production.

Notes

Economists generally refer to Solow residual as technology. But it is technology in the widest sense. It means not only newer ways of production or newer machinery or newer sources of power supply but also betterment in work organization, more efficient government regulation, degree of monopoly, educational level of labour force, better social institutional factors etc.

In growth accounting TFP does not have any sense without influence of capital of labour. If no capital and labour is there, no technological change can bring about change in output.



Did u know? On isolating the influence of production factors, there remains the influence of all other factors.

7.6 Total Factor Productivity Measurement: Different Approaches

There are five methods of measuring total factor productivity. The first two are growth accounting techniques and the other three are econometric tools.

1. **Data Envelopment Analysis (DEA):** This approach to productivity measurement is completely non-parametric and makes use of linear programming. This technique was first used by Farrell in 1957 and later it was operationalised by Charnes, Cooper and Rhodes in 1978. This approach compares the ratio of linear combinations of outputs over linear combinations of inputs. It defines that a firm is efficient which has highest output-input ratio for any combination of outputs and inputs. In some situation no firm may be efficient.
2. **Index Numbers (TFP):** In this approach, under a number of assumptions, it is possible to calculate A, the technology coefficient or TFP coefficient without a specified exact production function or rigidly assuming it to be uniform across observations. There are two indices: Solow Index (developed by Solow in 1957) and Translog index (developed by Diewert in 1976).

Solow Index: Solow index assumes that elasticity of substitution between labour and capital to be equal to one. In other words if interest goes up by 5% employment of labour will increase by 5%, it has an important implication that income shares of labour and capital remain constant. Solow index of TFP is equal to:

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

Translog Index: The translog index of TFP is equal to:

$$\Delta \ln TFP_t = \Delta \ln Y_t - \left[(SL_t + SL_t - 1) / 2 * \Delta \ln L_t \right] - \left[(SK_t + SK_t - 1) / 2 * \Delta \ln K_t \right]$$



Caution Where, Y is output, L and K are labour and capital respectively, SL and SK are shares of income of labour and capital respectively, TFP is total factor productivity.

Advantages of the index

1. It does not take rigid assumptions about elasticity of substitution.
2. It does not require technology progress to be Hicks neutral.
3. Specification of technology is flexible.
4. Method can easily handle multiple outputs and a large number of inputs.

Disadvantages of the index

1. It requires quality and reliable data.
2. It is impossible to account for measurement error.

Notes

Econometric methods: In econometrics, we apply regression analysis to estimate a production function and from estimated production function we get the rate of technical progress. Generally, Cobb-Douglas Production function is used. There are also Semi parametric procedures to address the issue of productivity.

Limitations of Total Factor Productivity Measures

- (a) Certain rigid assumptions make it unrealistic and hence limit its use in real life.
- (b) Econometric models do not take such rigid assumption and hence are appreciated but it assumes that same rate of technological progress for all the years under study. It is not so.



Task

What is solow index?

7.7 Issues and Debates Related to Total Factor Productivity

Some issues and debates total factor productivity are:

1. Dichotomy between technology and capital;
2. The slow down in productivity;
3. Productivity and information technology;
4. Productivity and environment.

Dichotomy between technology and capital: the dichotomy is about which is the cause of productivity: is it capital or technology ? There is empirical evidence for both.

The slow down in productivity: Another issue that is debated is the slow down in productivity in 1960s and 1970s. There is no satisfactory explanation for the reasons for such happenings.

Productivity and information technology: There is a strong correlation exhibited by empirical evidence between productivity and IT but there are no models to give a specific explanation.

Productivity and environment: Many environmentalists argue that the growth that is taking place at the cost of environment is doing more harm than good as the opportunity cost of environmental degradation are too high.

Self-Assessment

2. Multiple choice questions:

Choose the correct option

- (i) High productivity brings about standard of living.
 - (a) higher
 - (b) lower
 - (c) middle
 - (d) none of these
- (ii) When labour is raised by β , the proportional growth rate of a quality raised will be equal to.
 - (a) $\ln y = \alpha \ln L$
 - (b) $\ln y = \beta \ln L$
 - (c) $\ln y = (\alpha + \beta) \ln L$
 - (d) None of these
- (iii) In the DEA technique was first used by Farral.
 - (a) 1950
 - (b) 1955
 - (c) 1957
 - (d) 1960

7.8 Summary

- Productivity and growth are closely related concepts. Productivity refers to the rate at which resources are being utilized.
- Growth is increase in output over a period of tie. Output is the return of inputs which can be clubbed into labour and capital.

Notes

- Better technology can increase the efficiency of existing inputs.
- The main reason for some countries performing better than others is difference in their relative productivities.
- Economists generally refer to Solow residual as technology. But it is technology in the widest sense.
- Solow index assumes that elasticity of substitution between labour and capital to be equal to one.
- There is a strong correlation exhibited by empirical evidence between productivity and IT but there are no models to give a specific explanation.

7.9 Key-Words

- simultaneous : happening or done at the same time as something else.
- assumptions : a belief or feeling that something is true or that something will happen.
- attribute : to say or believe that something is the result of a particular thing.

7.10 Review Questions

1. Define and explain the concept of total factor productivity.
2. What are the factors that effect total factor productivity growth?
3. Taking a Cobb-Douglas production function, explain how you will explain change in output resulting from changes in capital, changes in labour and overall change in productivity?
4. What do you understand by "Solow Residual"? explain how total factor productivity is increased using the growth accounting method?
5. Discuss the various approaches to measuring total factor productivity.

Answers: Self Assessment

1. (i) productivity, growth (ii) productivity (iii) growth
(iv) FDI (v) increases
2. (i) (a) (ii) (b) (iii) (c)

7.11 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 8: Technological Change and Progress

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- 8.1 Technical Change and the Production Process
- 8.2 Classification of Technical Change
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- 8.4 Some Issues Related to Technical Change
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Objectives

After reading this unit students will be able to:

- Describe the technical change and the production process and classification of technical change.
- Understand the Neo-classical model with technical change.
- Know about the some issue related to technical change.

Introduction

Harrod-Domar model as well as Solow model did not consider the role of technology in growth and both are criticized also for it. This unit explains the meaning of technical progress; difference between technical progress and technical change; role of technical progress in growth and development. The unit also explains neo-classical growth model in the presence of technical change and relationship between technical change and total factor productivity. All economists have a consensus that technology plays a dominating role in determining the rate of growth and development of an economy. But here we are trying to develop a model that gives a precise and quantitative relationship between the two.

8.1 Technical Change and the Production Process

Technical change means improvement in production process. In other words, it means being able to produce more output with the same amount of inputs. With the technical progress, production function shifts upward. It makes production function superior to the one that existed before technical change. With the introduction of technology as an endogenous variable in production function, the production function becomes

$$Q = F(K, L, t)$$

Where, Q is quantity produced; K is capital employed; L is labour employed, t is technology. If we take $k = K/L$ and Y as Q/L , then we can write the per worker production function as:

$$Y = f(k, t)$$

There is another way to represent technological progress:

$$Y = F [J(t) K, Z(t) L]$$

Notes

With the introduction of coefficients $J(t)$ and $Z(t)$, the production is dependent not only the total amount of labour and capital employed. The expressions $J(t)$ and $Z(t)$ are called effective capital and effective labour respectively. If dZ/dt is more than zero, it shows that effective labour is increasing even though the actual labour force remains unchanged. Similarly, if dJ/dt is more than zero, it shows that effective capital is increasing even though the actual capital stock remains unchanged.

If dJ/dt is positive and $Z(t) = 1$ then it is purely capital augmenting technical progress. On the contrary, If dZ/dt is positive and $J(t) = 1$ then it is purely labour augmenting technical progress. If dJ/dt and dZ/dt both are positive, then it is called equally capital augmenting and labour augmenting. But the limitation is that it is silent on the cause and source of technical change.

If in an economy both effective labour and effective capital are growing at $x\%$, the factor augmenting technical progress is said to be taking place at $x\%$. If only effective labour is growing at $x\%$, then it is said to be purely labour augmenting technical progress at $x\%$. If effective capital is increasing at $x\%$, then it is said to be purely capital augmenting technical progress at $x\%$.



Notes

If the production process is experiencing constant returns to scale; then production function can be written as:

$$Y = A(t) F(K, L)$$

However, it is not at all necessary that technical change would be taking place at a constant rate.

8.2 Classification of Technical Change

Most of the technical changes either make production process more labour intensive or more capital intensive. And by changing the intensity of factors of production, these technical changes bring about a change in the relative share of these factors of production in total product. Certainly, if any technological progress makes production process more labour intensive, it will increase the share of labour in TP and *vice versa*. These technical changes affect the demand and supply of factors of production and thereby wage rate and interest.

To take a simple production function,

$$Y = F(K, L)$$

If capital per worker is denoted by k , output per worker by 1 , and worker output ratio by $m = 1/1$ and capital-output ratio by n

Then Capital-output ratio = capital-labour ratio * labour-output ratio

$$n = k * m$$

Or

$$k = n / m$$

m and n in the above equation are called technical coefficients. In other words, worker output ratio and capital-output ratio are called technical coefficients. k is called capital intensity. If k increases, it is called capital deepening; if k decreases, it is called labour deepening.

In order to get marginal product of capital and marginal product of labour, we can differentiate the production function with respect to capital and labour. Let us call it F_k and F_L then we can calculate second derivative to know the rate of change in their marginal products. Let us denote it by F_{kk} and F_{LL} .

Generally speaking, $F_k > 0$, $F_L > 0$ showing MP of labour and capital to be positive

And, $F_k < 0$, $F_{LL} < 0$ showing that both MP of labour and capital is increasing at a decreasing rate.

Along an isoquant, $Q = F(K, L)$ is constant. Hence for any change along an isoquant.

Loss in MP of one factor = gain in MP of other factor

Notes

Therefore, $F_k dk + F_L dL = 0$

With the help of these functions, we can also estimate Marginal rate of substitution between factors of production. If labour is substituted for capital then MRS_{KL} is equal to

$$-dK/dL = F_k/F_L$$

Product Exhaustion Theorem: It states that if the production function is exhibiting constant returns to scale, then sum total of products of marginal products of different factors and their price is equal to Total Product. $(\delta Y / \delta L)w + (\delta Y / \delta K)r = Y$.

where, $\delta Y / \delta L$ is MP of labour, w is wage rate, $\delta Y / \delta K$ is MP of capital and r is rate of interest. Therefore, if constant returns to scale prevail, total product gets exhausted in the shares of capital and labour.

Elasticity of Substitution: Elasticity of substitution is measured as a proportionate change in the ratio of the quantities of the two goods consumed divided by the proportionate change in marginal rate of substitution (MRS_{xy}) between the two goods along a given curve.

$$\sigma = \frac{\text{Proportionate change in ratio of two goods consumed}}{\text{Proportionate change in MRS}_{xy}}$$



Did u know? Elasticity of substitution is a relative measure of the degree of substitution between two goods for the consumption by the consumers.

Embodied and Disembodied Technical Change

Embodied capital change is the change that occurs due to the change in type of factor of production, usually capital. It involves introduction of new machines, new process of production, new product. On the other hand, disembodied capital change occurs when same amount and type of factors of production can produce more. It will happen when isoquant shift inwards showing the production of same output with lesser inputs. It is factor augmenting technical change.

Neutrality of Technical Change: Neutrality broadly means that technical change is neither labour saving nor capital saving. It means it reduces the usage of inputs in same ratio and does not affect the relative demand and supply of factors of production and hence, does not affect the prices of inputs. It must be clear from above that disembodied technical change is neutral.

Hicks's Classification of Technical Change

Sir John Hicks gave a classification of technical progress in terms of its effect on the ratio of marginal product of capital to marginal product of labour.

If after introduction of technology, MPK/MPL falls, it is capital saving. If it remains same, it is neutral. If it increases, it is labour saving.

Since at producer's equilibrium isoquant is tangent to iso-cost line i.e. $MPK/MPL = PK/PL = r/w$, where r is rate of interest and w is real wage rate. Therefore, Hicks's classification can also be expressed as follows:

If a technology increases r/w , it is labour saving, while if it decreases r/w , it is capital saving. If r/w remains unchanged the technological progress is unchanged.

In terms of production function, Hicks's classification of technological progress can be expressed as follows: A technical change is labour saving if it shifts the per worker production function upward or at any given value of capital-labour ratio, the ratio of marginal product of capital to marginal product of labour has increased. A technical change is capital saving if it shifts per unit of capital production

Notes

function upward or at any given value of capital-labour ratio, the ratio of marginal product of capital to marginal product of labour has decreased. If the ratio is unchanged, it is neutral.

It is proved by Uzawa that Hicks' neutral technical change is same equal to factor augmenting technical progress. Hence, Hicks's neutral technical change is equal to:

$$Y = A(t) F(K, L)$$

The version given by Hicks is based on marginal product of factors and their prices. Hence, it can be used to represent technical change in terms of relative shares of factors in total product.

The ratio of relative shares of factor inputs is $[rK/Y]/[wL/Y] = rK/wL$.

Keeping, K/L constant i.e. assuming capital-labour ratio to be constant, relative shares will be affected by changes in r/w . If for a constant K/L , relative shares of r/w are increasing, it is said to be labour saving. If for a constant K/L , relative shares of r/w are decreasing, it is said to be capital saving. If for a constant K/L , relative shares of r/w are unaffected, it is said to be neutral technical change.

Harrod's Classification of Technical Change

Sir Roy Harrod put forward his classification of technical change in an article in 1937 and expanded on it in his book which was published in 1948. He defined neutral technical change as one in which capital-output ratio remains constant in the presence of a constant interest rate. In other words, neutral technical change implies that given a constant rate of interest, the distribution of the total national product between capital and labour remains constant.

Mrs. Robinson provided a geometric proof that Harrod-neutral technical progress is equivalent to Hicks's Labour augmenting progress. She claimed that if technical progress is Harrod-Neutral, and is proceeding at a constant rate u , then the aggregate production function can be written as :

$$Y = F(K, Z(t)L) \text{ with } [dZ(t)/dt]/Z(t) = u$$

In Harrod's Model, a technical change is said to be labour saving if at a given capital-output ratio, the ratio of relative shares $S = rK/wL$ is increasing. In other words, if K/L is constant, and dS/dt is more than zero, then it is labour saving technical change. If K/L is constant, and dS/dt is less than zero, then it is capital saving technical change. If K/L is constant, and dS/dt is equal to zero, then it is Harrod neutral technical change.

The Harrod's neutrality can coincide with Hicks's neutrality if the distribution of income is same at all levels of capital-labour ratio. And, capital-labour ratio can be same at all levels if and only if elasticity of substitution between labour and capital is one.



Caution In a Cobb-Douglas production function unitary elasticity of substitution is exhibited by a function in which the sum of the coefficients of labor and capital is one.

$$Y = K^a L^{1-a}$$

Solow's Classification of Technical Change

Solow compared technical change by comparing points on old and new per worker production at which the labour-output ratio is constant. Hence, Solow said technological progress to be neutral when at points where labour-output ratio is constant, and dS/dt is zero. In other words, when the relative shares of capital and labour in total product remains constant. Solow neutral technical progress is Hicks's capital augmenting.

Self Assessment

1. Fill in the blanks
 - (i) With the technical program, production function shift
 - (ii) Technical changes effect the demand and supply of and there by wage rate and

Notes

- (iii) states that if the production function : exhibiting constant reforms to scale, then sum total of products of marginal products of different factors and then price is equal to total product.
- (iv) means that technical change is neither labour saving nor capital saving.
- (v) Sir John Hick gave a classification of technical program in terms of its effect on the ratio of marginal product of to marginal product of

8.3 The Neo-classical Model with Technical Change

A simplified Neo-classical model without technical change has already been explained in chapter 3. But we know that in the model, the key to growth was not capital accumulation but technical progress. The concept of Solow residual clarified that even after accounting for capital accumulation and growth in labour force, some part is left over. It is attributed to technical change.

Before we introduce technical change into neo classical model, we need to analyse, which classification of technical change is going to serve our purpose better.

With Hicks's Scheme: If labour force increases at a constant rate, g , and MPS is also constant, then the economy will reach at an equilibrium level of output per worker and an equilibrium level of capital per worker. If the economy is on balanced growth path, then with given fixed rate of growth of the labour and saving rate, any rightward shift in production per worker will mean that capital per worker has changed. It will give us new capital-labour ratio. But Hicksian approach assumes a constant capital labour ratio; therefore Hicksian classification of technical progress is not of much use.

It is clear from above explanation, that if we want our economy to grow steadily in the long run with technical progress, this technical progress has to be of Harrod neutral. The model is not talking about the complete schema of Harrod's classification of technical change but technical progress must be specifically, Harrod-neutral or labour augmenting.

If we consider Solow model of growth with labour being measured in terms of efficiency rather than natural units, it can be represented as :

$$Y = F(k, Z(t)L) \text{ where } Z(t)L \text{ is effective labour force.}$$

Now output per effective labour will be equal to:

$$y = Y/Z(t)L$$

and capital per worker in efficient units, $k = K/Z(t)L$.

if $Z(t)L$ is growing at a constant rate u , this means Harrod - neutral technical change is happening @ u . in this case, equation of the Solow model will be equal to :

$$k = sf(k) - (n + u)k$$

where , $sf(k)$ is savings per effective labour, $n + u$ is rate of growth of capital stock.

The steady growth rate occurs where this curve intersects the line $(n + u)k$.

8.4 Some Issues Related to Technical Change

There are some issues related to technical changes that are controversial and need to be discussed in detail to reach at an exhaustive solutions to the controversies associated with them but in this chapter we are limiting our presentation only to the issues and not to their solutions. In subsequent units, some of them will be answered.

What about Embodied Technical Progress?

It has been clarified that embodied capital change is the change that occurs due to the change in type of factor of production, usually capital. It involves introduction of new machines, new process of

Notes

production, new product. On the other hand, disembodied capital change occurs when same amount and type of factors of production can produce more. Disembodied technical change is exogenous for many growth models and it is not explained how does it happen. It seems to be a miraculous event.

Solow provided an index of effective capital in his paper 'Investment and Technical progress' published in 1960. Assuming embodied technical progress as an exogenous factor that too without any supporting theory for its explanation, makes it very difficult to understand the determinateness of embodied capital. Moreover, capital goods or machines may be of different vintages.

Therefore, we need to develop a model that gives a satisfactory explanation of the factors that determine the level of embodied progress and the process by which it takes place.

Nature of Capital

While discussing technical change attention has not been paid to the nature of capital. Machines are of different ages and types. It is difficult to give a precise value to the capital stock as there may be an index number problem. Kaldor was strongly against the idea of representing technical change by a shift in per worker production function. He opined that many a times, it becomes difficult to distinguish between the effect of capital accumulation and the effect of technical change. While the former will lead to movement along the curve; latter will shift the curve upward.



Task What do you mean by Embodied Technical progress?

Self-Assessment

2. State whether the following statements are 'true' or 'false'.
 - (i) If any technological program makes production process more labour intensive, it will increase the share of labour in TP and vice versa.
 - (ii) To get marginal product of capital and marginal product of labour, we can differentiate the production function with respect to capital and labour.
 - (iii) Hicks's neutral technical change is not equal to:

$$Y = (A) (\epsilon) F(K, L)$$
 - (iv) Sir Roy Harrod put forward his classification of technical change in an article in 1935.
 - (v) Embodied capital change is the change that occurs due to the change in type of factor of production, usually capitals.

8.5 Summary

- This unit explains the meaning of technical progress; difference between technical progress and technical change; role of technical progress in growth and development.
- Technical change means improvement in production process. Production function superior to the one that existed before technical change.
- by changing the intensity of factors of production, these technical changes bring about a change in the relative share of these factors of production in total product.
- In order to get marginal product of capital and marginal product of labour, we can differentiate the production function with respect to capital and labour.
- The version given by Hicks is based on marginal product of factors and their prices.
- If labour force increases at a constant rate, g , and MPS is also constant, then the economy will reach at an equilibrium level of output per worker and an equilibrium level of capital per worker.

Notes

8.6 Key-Words

- co-efficient : a human which is placed before another quantity and which multiplies it.
- Substitute : a person or thing that you use or have instead of the one you normally use or have.
- disembodied : (of soundx) coming from a person or place that cannot be seen or identified
- aggregate : a total number or amoutn made up of smallen amounts that are collected together.

8.7 Review Questions

1. Enhance the concept of effective capital and effective labour in aggregate production function.
2. Describe the classification of technical change.
3. Explain the concept of elasticity of substitution.
4. Bring out the difference between harrod Newtraity and solow Neutrality.
5. Discuss the neo-classical growth model in the pressure of Harrod-neutral technical change.

Answers: Self-Assessment

1. (i) upward (ii) factory of production, interest
(iii) product exhaustion theorem (iv) Newtrality
(v) capital, labour
2. (i) T (ii) T (iii) F (iv) F
(v) T

8.8 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 9: Economic Growth Model – III : Models of Optimal Economic Growth

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- 9.8 Further Readings

Objectives

After reading this unit students will be able to:

- Know about the optimization over time and Ramsey model of growth.
- Understand the golden rule of accumulation.
- Describe the cass Koopman model of growth.

Introduction

The growth process of an economy with the economic agents taking decisions. The unit focusses on the consumption and saving decisions. Since economic agents try to attain such a combination of consumption and savings that optimizes their utility hence these models are called optimal growth models. Such as this unit explains some new techniques of optimization. Temporal techniques of optimization followed by Ramsey model of growth. Optimal level of savings is explained under the golden rule of accumulation. At last, the Cass Koopman's model which is an extension of Ramsey model has been explained.

9.1 Optimization Over Time

We have already learnt about static optimization techniques i.e. optimization at a given point of time with or without constraints. We have also learnt about some dynamic processes but have not understood how to optimize over the time?

There are situations which call for optimization over a period of time. Optimization over time can be explained differently for two situations. One, when he takes decision at $t = 1$ for all periods 1, 2, 3, 4, 5..... n . and second, when he optimizes subsequently for each time period. It is possible when each period is separable and separate decisions can be made in different periods.

Let there is a consumer who makes a choice between two time periods p and f . p can be called present and f can be called future. Let the consumer's consumption is c_1 and c_2 in two periods respectively.

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Let he has income m_1 and m_2 for the two periods respectively.

Consumer is assumed to be free to borrow and lend. If he chooses to borrow, he has to pay a rate of interest equal to r and if he saves a part of income and lends it out, he can earn an interest equal to r . If he decides to lend a part of her income, then his budget constraint in the period f would be:

$$c_2 = m_2 + (m_1 - c_1) + r(m_1 - c_1)$$

c_2 is consumption that he can afford in period f ;

m_2 is income in period f ;

$m_1 - c_1$ is income saved in period p ;

$r(m_1 - c_1)$ is interest on income saved in period p .

If the consumer might have decided to borrow in period p , then his budget constraint in the period f would be :

$$c_2 = m_2 - (c_1 - m_1) - r(c_1 - m_1)$$

This equation can be written as :

$$c_1 + \frac{c_2}{(1+r)} = m_1 + \frac{m_2}{1+r}$$

If we invest Rs. x for a period of time, then interest rate compounded annually will become equal to $P(1+r)^a$

In this case, the present value of stream of payments can be written as:

$$\begin{aligned} & \frac{c_1}{1+r} + \frac{c_2}{(1+r)^2} + \frac{c_3}{(1+r)^3} + \dots + \frac{c_n}{(1+r)^n} \\ &= \sum_{i=1}^n \left[\frac{c_i}{(1+r)^i} \right] \end{aligned}$$

If $1+r$ is denoted by a :

$$\sum_{i=1}^n \left[\frac{c_i}{(ac)^i} \right]$$

Meaning of Functional: A quantity that is dependent on a variable function is called functional. Question arises, what a variable function is ? A variable function is one which does not choose a single optimal value of a variable quantity but a function i.e. a pattern of relationship. When we optimize at a point of time, (it is called static optimization) a single optimal magnitude for every chosen variable is sought to be obtained. On the contrary, in dynamic optimization i.e. when we optimize over a period of time, the problem is to reach at the optimal magnitude of the chosen variable in each period of time in the given time horizon of the optimization problem.

Time period may be discrete or continuous. However, in both time periods, a dynamic optimization problem would contain following ingredients:

- (a) A given starting point and a given termination point which can be infinity;
- (b) A set of admissible from starting to termination point;

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- (c) A set of path values, and
- (d) A specified objective to maximize or minimize the path value by choosing the optimal path.

The relationship between path and path values is shown by a special type of mapping from entire paths curves to real numbers. Let us assume we have a variable x that depends on time. Let x also depends on many other variables such that $x = f(t)$; $x = g(t)$; and $x = h(t)$. Let the value associated with three functions is v_1 , v_2 and v_3 respectively. This relationship between the various types of functions which can be generally denoted by $x(t)$ and the v values are called functional. It can be expressed as :

$$v = [x(t)]$$

In differential standard calculus, if we have $y = f[h(x)]$, it means that some variable is a function of x and y in turn is a variable of this function. Therefore, y is indirectly a function of x . Such functions is called composite function.

There are three methods to solve dynamic optimization problems :

- (a) Calculus of Variations;
- (b) Optimal Control; and
- (c) Dynamic Programming.



Task

What is the meaning of functional?

9.2 The Ramsey Model of Growth

Economists like Pigou identified that people tend to underestimate future utility and hence, do not save enough for the future. This implies that actual savings fall short of the optimal savings. Frank Ramsey tried to answer the question: What should be optimal saving ? And how can it be calculated?

Ramsey's model is prescriptive in nature and not predictive. The society has to choose optimal economic growth. If we assume society is being represented by a 'Representative Agent' or a central planning agency, which aims at maximizing utility function which depends on consumption, we can show it as follows:

$$U = F(C)$$

Utility in each time period depends on the utility in that time period.

$$U = F(C_t)$$

If labour and capital are denoted by L and K respectively, we can say:

$$U = U(C, K)$$

$$U = U(C/L)$$

$$U = LU(C/L)$$

if $C_t = c$ then

$$U = U(c)$$



Notes

Hence, it proves Keynesian version that consumption is the sole end and object of all economic activity.

Notes

Suppose the time periods be 0, 1, 2, 3, ...T. There is a stream of consumption over time periods 0.....T, that can be denoted as $[C_1, C_2, C_3, \dots, C_T]$. This is sequence of consumption. A sequence is a quantity arranged in order. The optimization problem is to choose such a sequence of consumption that maximizes utility. The idea is to optimize the utility function over entire path so the maximization problem is:

$$\text{Maximize } J = \sum_{t=0}^T U[c(t)]$$

Several points that need to be paid attention regarding objective function :

- J is the value of sum total of the utility function, since the particular utility function here is additive separable. It means that utility in period 1 is not dependent on utility in period 2.
- Time is a discrete variable and appears as an argument of the consumption function.
- If time would have been taken as continuous, the objective function would have been like :

$$J = \int_0^T U[c(t)] dt$$

- The term J is functional. Utility depends on the whole path or the whole function c. If c changes U will change. Similarly if c changes, J will change. Therefore, in optimization problem, what is being maximized is functional.

Ramsey used a mathematical technique called calculus of variations to solve the optimization problem above. He thought of an ideal level of utility and called it bliss point and assumed it to be same for all time periods. He saw how much actual utility falls short of bliss point. Let B shows the ideal utility i.e. bliss point. It is same in all time periods! Let $U(ct)$ be the actual utility from per worker consumption level c. Then we can define a function.

$$\text{Maximize } J = \sum B - U(ct)$$

Certainly, this optimization is subject to the constraint of growth of capital stock of the economy.

Now, let us come to the question of choice of time horizon. If we take time to be finite, and we find that we are left with some capital stock at the termination of time period T, then optimum has not been reached and the optimization function given above would not have been optimized. Therefore, it is desirable to specify a terminal condition that some capital is retained at time T, or the other option is to take time horizon till infinity.

Then there comes a problem of discounting. Given that people value present more than the future, should we discount future values? Ramsey opposed it.



Did u know? Social welfare should not only depend only on the current members of the society, but of all members of the society who will live in the society in future.

Self-Assessment

- Fill in the blanks:
 - There are situations which call for over a period of time.
 - Economists like identified that people tend to underestimate future utility and hence do not save enough for the future.
 - model is prescriptive in nature and not predictive.

- (iv) Ramsey used a mathematical technique called of variations to solve the optimization problem.
- (v) Time is discrete variable and appears as an argument of the function.

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9.3 The Golden Rule of Accumulation

The equation for “Golden Rule of Accumulation” was put forward by Edmund Phelps in 1961. The concept started with a question in context of optimal growth: what is the saving rate that gives rise to the steady path with the highest levels of c i.e. consumption per labour? Answer is that the highest steady path for c , is the one that is equivalent to the highest steady state value of c . Therefore, we need to find out the highest rate of savings that generates the highest steady state value of c , given the values of n and d where n is exogenously given rate of growth of population and d is the rate of depreciation.

In National income identity

$$Y = C + I \text{ where } C \text{ is consumption and } I \text{ is investment}$$

Therefore,

$$C = Y - I$$

If we divide both sides by population we can get per capita values. Let us denote it by small letter

$$c = y - i$$

It can be written as :

$$c_t = f(k_t) - sf(k_t)$$

It implies that saving equal investment and saving equals sY . s stands for MPC.

$y = f(k_t)$ is the consumption function that is to be maximized given a constraint that the rate of growth of capital should be equal to zero. Therefore, the objective function is :

$$c_t = y_t - i_t$$

Subject to $k = 0$.

Therefore, the function can be written as :

$$\text{Maximize } c_t = f(k_t) - sf(k_t)$$

$$\text{Subject to } sf(k_t) = (n + d)k_t$$

On substituting the constraint in the objective function,

$$\text{Maximize } ct = f(k_t) - (n + d)k_t$$

So the first order condition for solution to this problem is :

$$dc / dk_t = f(k_t) - (n + d) = 0$$

It implies that :

$$f(k_t) = (n + d)$$

This equation is known as Golden Rule of Accumulation. The solution to the equation will give us the steady state value of k : which in turn will steady path for c_t that can be attained given the values of n and d .

It is called a golden rule as it takes care of the interest of present as well as future generation. The idea communicates that our previous generations saved as so that we could enjoy optimal levels of consumption. Now we should also save as so that our future generations can also enjoy optimal consumption paths.

9.4 The Cass Koopmans Model of Growth

This model was developed by David Cass and Tjalling Kopsman. The model is an extension of Ramsey model. Ramsey opined that discounting future is morally and ethically undesirable as equal importance should be given to present as well as future. But David Cass and Tjalling, Kopsman believed that it is necessary to discount future values when it is clearly known that the society attaches greater value to the present than future. The reasoning put forward for discounting future values is mathematical and logical in nature.



Caution They also criticized Golden Rule of Accumulation and claimed that objective function should aim at maximization of utility and not consumption.

The David Cass and Tjalling Kopsman formulation can be explained as follows:

If we assume that the society has a utility function equal to $U(c_t)$ and the stream of utility accruing to society $\{U_1, U_2, U_3, \dots, U_t\}$ then the total utility can be derived by simply adding up utilities in different time periods as per Ramsey Model. In other words, Ramsey model would give us total utility which is equal to :

$$U_0 + U_1 + U_2 + \dots + U_t.$$

But David Cass and Tjalling Kopsman model does not accept it. Following arguments are given for it :

- (a) The society is not indifferent to timings of utility. It values present more than the future and therefore attaches greater value to present utility than future utility. Therefore the society has a time preference. It implies that total utility of the society can n to be determined by simply adding up the utilities in different time periods but it needs to be discounted. Therefore, David Cass and Tjalling Kopsman advocated tat total utility should be calculated by computing the present discounted value of the utility stream which is equal to :

$$U = U_0 + \frac{U_1}{(1 + \alpha)} + \frac{U_2}{(1 + \alpha)^2} \dots$$

Where α is the rate of time preference or discount rate. If we denote $1/(1 + \alpha)$ by a , and call a as discount factor, then

$$U = U_0 + aU_1 + a^2U_2 \dots$$

Hence, the first reason put forward for inculcating the discounting of future utility is simple that the social planner has a preference for present utility to future utility.

- (b) The second argument put forward for using discounting is that we are not as concerned for the future generations as we are for our own dynasties. Each individual is concerned the most about his own family members which include his children and thereby future generation but not for the future generations at large. Therefore each person's utility in the current period is also a function of the utility of his or her children in the future.
- (c) Robert Becker has put forward still another argument for discounting future utilities. He advocates that inter-temporal optimization must not be understood in a normative perspective. It does not involve value judgments. If it is a fact that society values present more than the future, it is not desirable to attach a value judgment that the society should not do so.

After having explained the rationale for discounting, let us explain how optimization is attained with discounting of future utilities.

Cass Koopman's Model assumes that there is a representative agent of the society who aims at maximizing an inter-temporal utility function:

$$U = U_0 + aU_1 + a^2U_2 + \dots$$

Where a is the discount factor and $0 < a < 1$

The utility function given above is additively separable over time.

Let us now understand with the help of Sidrauski Model the impact of money on optimization equations and conditions.

The basic idea in the Sidrauski Model is to introduce real money balances into the utility functions. He claims that a consumer gets utility not only from consumption but also from, holding real the money balances money balances. But he talked about real money balances i.e. that have been adjusted for the price rise in the economy. Therefore, the utility function put forward by Sidrauski is :

$$U = F(c_t, m_t)$$

$m_t = M_t/P_t$. In other words, m , is the real money balances which are derived by dividing M_t , the nominal money balances by P_t i.e. price levels.

Sidrauski Model also faces the same constraint as Cass Koopman's Model.

$$c_t + k_t = f(k_t) + (1-d)k_t$$

Rather it has an additional constraint due to introduction of money. So we introduce :

$$V_t = \frac{\bar{M}_{t+1} - \bar{M}_t}{P_t}$$

Where $\bar{M}$ denotes money supplied from outside by the government. It is different from $\bar{M}_t$ which means the money balances chosen by an individual. New Budget equation will be :

$$P_t(c_t + k_t) + M_{t+1} = P_t[f(k_t) + (1-d)k_t] + M_t + P_t V_t$$

If we take inflation rate as x then:

$$\frac{M_{t+1}}{P_t} = \frac{M_{t+1}}{P_t} \left(\frac{M_{t+1}}{P_{t+1}} \right) \left(\frac{P_{t+1}}{P_t} \right) = M_1 + (1+x_t)$$

The above equation can be used to solve optimization exercise and find out whether economy is in stationery state or is growing.

Self-Assessment

2. State whether the following statements are 'true' or 'false'.
 - (i) The equation for "golden rule of accumulation" was put forward by Edmund Phelps in 1961.
 - (ii) The model is not an extension of Ramsey model.
 - (iii) Robert Becker has put forward still another argument for discounting future utilities.

9.5 Summary

- Since economic agents try to attain such a combination of consumption and savings that optimizes their utility hence these models are called optimal growth models.
- A quantity that is dependent on a variable function is called functional. A variable function is

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one which does not choose a single optimal value of a variable quantity but a function i.e. a pattern of relationship.

- The relationship between path and path values is shown by a special type of mapping from entire paths curves to real numbers.
- Economists like Pigou identified that people tend to underestimate future utility and hence, do not save enough for the future.
- Ramsey's model is prescriptive in nature and not predictive. The society has to choose optimal economic growth.
- Ramsey used a mathematical technique called calculus of variations to solve the optimization problem.
- The equation for "Golden Rule of Accumulation" was put forward by Edmund Phelps in 1961.

9.6 Key-Words

- optimal : the best possible
- extension : the act of increasing the area of activity, group of people, etc.
- Magnitude : the great size or importance of something.

9.7 Review Questions

1. What are the basic elements or ingredients of a dynamic optimization problems.
2. Explain the concept of a functions
3. Describe the basic structure of optimization in the Ramsey growth model.
4. What do you understand by the "Golden Rule of Accumulation"?
5. Suppose there is a technical change in Neo-classical models How would then the golden rule need to be modified?
6. What are the reasons for the use of discounting in the cars-koopmans model?

Answers: Self-Assessment

1. (i) optimization (ii) pigon (iii) Ramsey's
(iv) calculus (v) consumption
2. (i) T (ii) F (iii) T

9.8 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 10: Multi-Sector Models of Growth

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Objectives

After reading this unit students will be able to:

- Explain the two-sector growth models.
- Describe the multi-sector growth models.

Introduction

The assumption that we had taken in one sector growth model that there is one good that is used both as capital as well as consumer good is very unrealistic and is criticized for the same. The multi-sector growth models are a class of growth models that reject this assumption. These models have a two-sector model as a special case. It recognizes that consumption and capital goods are inherently different commodities and are produced in different sectors of the economy. Multi-sector models explain the situation where many durable goods are produced with fixed coefficient or a neo-classical type production function. The theory was popular during 1950-1970 but lost its image and many supporters when endogenous theories came into the picture.

10.1 Two-Sector Growth Models

Introduction and Assumptions: All two sector models assume that a single homogenous good is produced using homogenous capital and labour. Capital and labour are also assumed to be homogenous. This homogenous capital good is also produced in a sector using homogenous factors of production. Hence, there are some common assumptions of all two sector models :

- There is one single capital good which is used in both the sectors as an input. Say for example the economy produces 'Wheat' in one sector using tractors and labour and 'tractors' in other sector using tractors and labour.
- All labour is homogenous which implies there are no differences in skills that they have and it grows at a constant rate and this growth rate is an exogenous variable.
- Both labour and capital are shiftable from one sector to another without any cost as such and instantaneously.
- Physical capital depreciates at a constant exponential rate δ .
- The conditions of competitive equilibrium are obtained.

Notes

The Uzawa Model

Hirofumi Uzawa put forward this growth model in 1961 and 1963 via his articles. Uzawa's model is a two sector extension of So low-Swan Neo-classical growth model.

Let us assume that there are two goods a consumer good say corn denoted by c , and a capital good tractor denoted by k . Both the goods are being produced under constant returns to scale. Therefore, the production function of both the goods are:

$$Y_k = F_k(K_k, L_k)$$

$$Y_c = F_c(K_c, L_c)$$

Where K_k and L_k are the amounts of capital and labour employed in the production of capital good and K_c and L_c are amounts of capital and labour employed in the production of consumer good. Let

$$k = K_k + K_c \text{ and}$$

$1 = L_k + L_c$ then since we have assumed that labour and capital are shiftable in the two sectors, therefore the production function of the two sectors can be written in per-worker form as :

$$y_k = F(k_k)$$

$$y_c = F(k_c) \text{ where } Y_k = Y_k/L_k; k_k = K_k/L_k; y_c$$

$$= Y_c/L_c; k_c = K_c/L_c.$$

It is assumed that labour grows at a constant rate.

$$\frac{\dot{L}}{L} = n = g_L$$

On the basis of the assumptions that both the sectors are minimizing profits and the wage rate and the rental profile are same in both sectors therefore,

$$P_k = \frac{\partial Y_k}{\partial K_k} = r, \text{ and}$$

$$P_c = \frac{\partial Y_c}{\partial K_c} = r;$$

$$P_k = \frac{\partial Y_k}{\partial L_k} = w, \text{ and}$$

$$P_c = \frac{\partial Y_c}{\partial L_c} = w$$

where P_k is the price of capital good and P_c is the price of consumer good.

$\frac{w}{r}$ is the ratio of wage rate to rental capital.

Rental capital is a function of the physical marginal product of the capital in the capital goods sector and the consumer goods sector.

Notes

Euler's theorem will operate in both sectors because it is assumed that constant returns to scale are provided therefore wages in capital goods sector are $w = P_k Y_k - k_k P_k F'(K_k)$

Similarly wages in consumer goods sector are:

$$w = P_c Y_c - K_c P_c F'(k_c)$$

It implies $\frac{w}{r} = \frac{F(k_k)}{F'(k_k)} - K_k$ in capital goods sector;

and $\frac{w}{r} = \frac{F(k_c)}{F'(k_c)} - K_c$ in consumer good sector,

Like Kaldor if we make on entre assumption that all profits are saved and all wages are communed given above facts, in the equilibrium the following conditions are satisfied:

$$Y_k = S_k(Y_k, L_k), Y_c = L_c(K_c, L_c)$$

$$P_k \frac{\partial Y_c}{\partial K_c} = r, P_c = \frac{\partial Y_k}{\partial L_k} = w$$

$$P_c \frac{\partial Y_c}{\partial K_c} = r, P_c = \frac{\partial Y_c}{\partial L_c} = w$$

$$K_c + K_k = K, L_c + L_k = L$$

$$P_c Y_c = w L, P_k Y = r K$$

If we assume that capital goods sector has two uses:

1. To replace net increases in the stock of capital goods.
2. To replace the depreciating capital goods then the rote of capital stock is:

$$\dot{K} = Y_k - \delta K$$

Saving-Investment equation is:

$$Y_k = \frac{rk}{P_k}$$

Putting it in equation given above,

$$\dot{K} = \frac{rk}{P_k} - \delta K$$

On solving the equation, we get

$$\delta'(K_k) = (n + \delta)$$

Therefore, if Kaldor's type of assumption about saving and investment is taken in Uzawa model then we can say that balanced growth path would be attained when the marginal product of capital in the capital goods industry is equal to the sum total of growth in the labour force and a constant rate of depreciation. Such a balanced growth path is possible to be attained if the capital-labour ratio in the consumer goods sector is never less than capital-labour ratio in the capital goods sector.



Notes

If above condition is fulfilled, it would not make any difference what is the ratio of wages and profits.

Notes

The Uzawa-Srinivasan Extension

Uzawa and Srinivasan both extended initial Uzawa model to explain a model of optimal growth in a two sector economy. They based their model on the assumption that there is a decision-maker who aims to maximize the sum of per capita consumption subject to the different production conditions and the conditions about the use of the capital good in both the consumption good and capital goods industry. They postulated a maximization function as follows:

$$\text{Max} \int_0^{\infty} y_c e^{\beta t} dt$$

Outcomes of the Model:

- The Uzawa-Srinivasan model investigates the situations in which the capital-labour ratio in the consumer goods sector is more than or equal to capital-labour ratio in the capital goods sector and also the situations in which the capital-labour ratio in the consumer goods sector is less than capital-labour ratio in the capital goods sector.
- Unlike Uzawa model, it is not a condition for balanced growth that the capital-labour ratio in the consumer goods sector is never less than capital-labour ratio in the capital goods sector.
- The objective in the model is not the balanced growth path but the optimization of growth path.
- The model aims at maximization of consumption per capita and not the utility and therefore the law of diminishing marginal utility does not hold well.



Did u know? Optimization exercise may be carried out by the individuals or government and some public sector agency.

The Feldman Model

G. A. Fredman was a Russian economist who worked to solve the problems of planning in the newly formed Soviet State Planning Commission. The Fredman Model is very much different from the Uzawa two-sector model.

Assumptions of the Model

- The Feldman Model assumes that the economy is divided into two sectors such that sector A produces capital goods and these capital goods can be used in either sector but once installed they can't be shifted from one sector to another.
- The Fredman Model assumes that production of goods in sector 1 is independent of production of goods in sector 2.
- The Model also assumes that the economy is a closed economy.
- The Model claims that capital does not depreciate at all and hence capital is equal to investment.
- The Feldman model assumes that production is carried out in both the sectors with fixed coefficients technology.

Two implications of the Feldman model are as follows:

- Generally speaking, in an economy the rate of consumption is not equal to rate of investment. With the time, the rate of the growth of the consumption increases until it reaches the long run growth rate of the economy. It is given by the rate of investment which is equal to a/w_1 .
- Another important fact revealed by the model is that the generally the rate of growth of the national income is not equal to the rate of growth of total investment. It will tend to be equal to a/w_1 in the long run. Therefore, the model suggests that it is advisable for policy makers to increase the proportion of current capital goods engaged in producing more capital goods as this will increase the rates of growth of consumption, investment and output in the long run.

The Feldman Model influenced the model developed by P.C. Mahalanobis who divided the capital goods sector into two types of capital goods : C-Type capital goods that produce consumer goods and K type capital goods that are used to produce other capital goods.

Notes



Caution Hence, to conclude we can say that P.C. Mahalanobis gave a model which is an extension of Feldman's model when there is more than one type of capital goods.

Self-Assessment

1. Fill in the blanks:
 - (i) All two sector models assume that a homogenous good is produced using homogenous capital and labour.
 - (ii) The conditions of competitive equilibrium are
 - (iii) Hirofami Uzawa put forward this growth model in and via his articles.
 - (iv) Uzawa's model is a extension.
 - (v) The rate of of consumer goods sector is dependent on investment.

10.2 Multi-Sector Growth Models

We have three Multi-Sector Growth Models:

- (a) The General Multi-Sector Model
- (b) Dynamic Leontief Model
- (c) Von Neumann Model.
- (a) **The General Multi-Sector Model:** This model contends one sector or two sector models by adding more sectors, each denoting an additional durable good product by Solow type production function.

Assumptions

1. There are 'N' distinct capital goods, each is being produced in a different sector of the economy.
2. Labour is homogenous.
3. There is one consumer good sector.
4. $k_1, k_2, k_3, \dots, k_n$ denote stocks of capital in different sectors.
5. k_{ij} denote i th capital good employed in j th sectors.
6. L_j denote labour employed in j th sector.
7. Production takes place under neo-classical production function.

$$Y_j = f(L_j, k_{1j}, \dots, k_{nj})$$

Since these functions show constant returns to scale, on multiplying each term by $\frac{1}{y_j}$, we get

$$1 = f(a_{0j}, a_{1j}, \dots, a_{nj})$$

Notes

Where $a_{0j} = \frac{L_j}{Y_j}, (j = 0, 1, \dots, n)$

$$a_{1j} = \frac{K_j}{Y_j}, (j = 0, 1, \dots, n)$$

Given above facts, full employment equilibrium will be attained when following conditions are fulfilled.

$$\sum_{j=0}^n a_{0j} Y_j = L_i$$

and $\sum_{j=0}^n a_{1j} Y_j = K_i$



Task

How many types of multi-sector growth models?

- (b) **Dynamic Leontief Model:** Dynamic Leontief Model is an extension of static input-output model of inter-industry analysis.

The model assumes that there is a single technology of production for the production of each good. In other words, it assumes a fixed coefficient of technology.

The model considers following type of production function.

$$Y_j = \min \left[\frac{L_j}{a_{0j}}, \frac{K_j}{a_{1j}}, \dots, \frac{K_{nj}}{a_{nj}} \right]$$

$(j = 0, 1, 2, \dots, n)$

Physical structure of the model can be explained in the following words :

The total demand for the i th good in t th period is :

$$\sum_{j=1}^n a_{ij} x_j(t) + \sum_{j=1}^n b_{ij} [n_j(t+1) - n_j(t)] + c_i(t)$$

Where $A = [a_{ij}]$ is a ' $n \times n$ ' matrix

$B = [b_{ij}]$ is also ' $n \times n$ ' matrix

$x_i(t)$ is the output of i th good in t period.

$c_i(t)$ is final demand.

$a_{ij} = i^{\text{th}}$ good used per unit of j th good.

b_{ij} is the quantity of i th good invested by the j th industry to increase the output in that industry by one unit.

Notes

$$K_i(t) = \sum_{j=1}^n K_{ij}(t) \quad \dots$$

(1)

Where $K_i(t)$ is the total stock of i th good required as a capital good in period t .

If we consider

b_{ij} = the amount of stock of i th good necessary as a capital good in the industry for the production of one unit of i th good, then

$$b_{ij}x_j(t) = k_{ij}(t) \quad \dots$$

(2)

Putting (2) in eqn (1), we get

$$k_i(t) = \sum_{j=1}^n b_{ij}x_j(t)$$

Further, let us assume that the capital is perfectly mobile from one sector to another and is fully employed, then

$$\begin{aligned} I_i(t) &= \Delta K_i(t) \\ &= K_i(t+1) - k_i(t) \\ &= \sum b_{ij} [x_j(t+1) - x_j(t)] \end{aligned}$$

Now, the basic equation of dynamic Leontief model can be written as :

$$x_i(t) = \sum_{j=1}^n a_{ij}x_j(t) + \sum_{j=1}^n b_{ij} [x_j(t+1) - x_j(t)] + c(t)$$

In matrix form, it can be written as:

$$x(t) = A \cdot x(t) + B \cdot [x(t+1) - x(t)] + c(t)$$

(c) Von Neumann Model*Assumptions*

1. The economy produces n commodities indexed by $i, i = 1, \dots, n$.
2. For every i , there is at least one j such that $b_{ij} > 0$. In other words, every commodity can be produced by some output.
3. With given technologies, production possibilities can be described by the transformation set T has as element pairs (x, y) of n -vectors such that the possible of output $y = (y_1, \dots, y_n)$ is possible technically from the input $x = (x_1, \dots, x_n)$ if only of (x, y) is a members of set T .
4. There are a finite number of production activities, M_1 indexed by j such that $J = 1, 2, \dots, n$.
5. The j th activity's operation at unit level requires an input $(a_{1j}, \dots, a_{nj})$ of the n commodities and produces an output $(b_{1j}, \dots, b_{mj})$ given that $a_{ij} \geq 0$ and $b_{ij} \geq 0$.

The model suggests that there is a transformation set which shows the relationship between activities and commodities T .

$$T = \{(n, y) : n \geq, A_z, y, < B_z\}$$

For some $z \geq, 0, z = (z_1, \dots, z_m)$

A_{ij} and B_{ij} are input and output coefficient respectively.

Notes

He claims that there exists an activity level z^* and a price level P^* such that

$$z^* \geq 0, P^* \geq 0, B_z^* \geq \lambda^* A_z^*, P^* \beta \leq \lambda^* A$$

λ is an eigen vector λ^* is the growth rate of the slowest growing sector.

Self-Assessment

3. Multiple choice questions:

Choose the correct option

(i) There are types of multi-sector growth models.

- (a) one (b) two (c) three (d) four

(ii) $\sum_{j=0}^n a_{oj} y_j = \dots\dots\dots$

- (a) L_j (b) L_i (c) L_k (d) L_n

(iii) $\sum_{j=0}^n a_{ij} y_s = \dots\dots\dots$

- (a) L_i (b) K_j (c) K_i (d) L_j

10.3 Summary

- The assumption that we had taken in one sector growth model that there is one good that is used both as capital as well as consumer good is very unrealistic and is criticized for the same. The multi-sector growth models are a class of growth models that reject this assumption.
- All two sector models assume that a single homogenous good is produced using homogenous capital and labour.
- Hirofumi Uzawa put forward this growth model in 1961 and 1963 via his articles. Uzawa's model is a two sector extension of Solow-Swan Neo-classical growth model.
- Rental capital is a function of the physical marginal product of the capital in the capital goods sector and the consumer goods sector.
- Uzawa and Srinivasan both extended initial Uzawa model to explain a model of optimal growth in a two sector economy.
- The Uzawa-Srinivasan model investigates the situations in which the capital-labour ratio in the consumer goods sector is more than or equal to capital-labour ratio in the capital goods sector and also the situations in which the capital-labour ratio in the consumer goods sector is less than capital-labour ratio in the capital goods sector.
- G. A. Fredman was a Russian economist who worked to solve the problems of planning in the newly formed Soviet State Planning Commission. The Fredman Model is very much different from the Uzawa two-sector model.

10.4 Key-Words

- Assumption : the act of taking or beginning to have power or responsibility.
- Durable : likely to last for a long time without breaking or getting weaker.

10.5 Review Questions

Notes

1. What are the basic assumptions that are common to all types of two-sector growth models?
2. Describe the basic structure of the uzawa model.
3. In what basic way is the feldman model different from the uzawa model?
4. Describe the basic structure of the general multi-sector production process.
5. Bring out the basic dissimilarities between the dynamic leontief model and von neumann model.

Answer: Self-Assessment

1. (i) single (ii) obtained (iii) 1961, 1963 (iv) two-sector
(v) growth
2. (i) (c) (ii) (b) (iii) (c)

10.6 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 11: Endogenous Growth Models

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Introduction

11.1 The Neo-classical Growth Model with Human Capital

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Objectives

After reading this unit students will be able to:

- Explain the neo-classical growth model with human capital.
- Describe the endogenous technology increasing returns and monopolistic competition.
- Understand the some issues in endogenous growth theory.

Introduction

Endogenous growth theory began with the efforts of Paul Romer in 1986 and Robert Lucas in 1988. Endogenous growth models originated in two sources : a0 to give a coherent explanation of convergence controversy, and the other, to go beyond an unrealistic simple world of perfect competition and constant returns to scale in growth models. Their work differs from Neo-Classical economists who took economic growth is caused by factors that are exogenous. The endogenous growth theory is an extension of Solow Model in the sense that the latter introduced increasing and diminishing returns to the theories of economic growth but the latter al so included technical change as an endogenous variable in growth models.

11.1 The Neo-classical Growth Model with Human Capital

Solow growth model stated that if initial conditions were similar in different countries, eventually the levels of income of these countries would converge. In other words, it claimed that the growth rate will be faster in poor countries than in rich countries and gradually income inequalities amongst nations would disappear. But empirical study brought into light two facts :

- (a) Growth rate of almost all economies of the world has been faster than population growth.
- (b) The growth rate of different nations did not converge for a very long time as claimed by Solow.

Hence, a need was recognized to build models where there is infinitely rise in per capita income: This research continued to consider capital accumulation as one of most determining factor in economic growth but in this model the meaning of capital accumulation has been broadened by including human capital into it. Mankiw, Romer and Weil gave a marginal extension to the neo-classical model in their paper that published in 1992. They considered human capital not as part of labour but a distinct factor of production. The model maintains Solow's assumption of diminishing returns to the capital as a factor of production.

The structure of the Mankiw, Romer and Weil model can be presented by assuming an economy which produces output Y using physical capital in combination with human capital. According to constant returns to scale, Cobb-Douglas production function will be:

$$Y = K^a (AL)^{1-a}$$

Where A is coefficient of labour augmenting technology which is growing at an exogenous rate g .

How do people accumulate Human Capital?

Different economists have various views on how people accumulate human capital. According to Mankiw, Romer and Weil people sacrifice their present consumption to accumulate human capital.

Lucas opined that people spend on accumulating new and scarcer skills which enhances their economic worth. The idea was proposed first of all by Kenneth Arrow in his article, "The Economic Implications of Learning New Skills and Foregoing Working for that Period" in the year 1962.

We are explaining a type of presentation given by Lucas.

If q is the proportion of time spent in learning new skills and L be the total amount of raw labour used in production. When L amount of the unskilled labour spends q proportion of their time on learning new skills then let us assume that H amount of skilled labour is produced as per following function:

$$H = e^{\phi q} L$$

Where ϕ is a constant.

It claims that if in an economy, $q = 0$, $L = H$, and all labour is unskilled then by raising q , the effective unit of H i.e. skilled labour can be increased.

Now let us see how does capital accumulation take place. Like in the Solow model,

$$\dot{K} = S_k Y - \delta K$$

Dividing above eqn by stock of unskilled labour, L

$$\frac{\dot{K}}{L} = \frac{S_k Y}{L} - \frac{\delta K}{L}$$

The model assumes q to be constant and an endogenous variable, $h = e^{\phi q}$ hence is a constant. Therefore, along a balanced growth path.

Rate of growth of K and $L = g$ i.e. rate of technical progress.

$$\tilde{y} = \tilde{k}$$

Where

$$\tilde{k} = S_{ky} - (n + g + \delta) \tilde{k}$$

$$\frac{\tilde{k}}{\tilde{y}} = \frac{S_{ky}}{n + g + \delta}$$

Putting this eqn into the production function in terms of the equation involving y , we can find the steady state value of output technology ratio y^*

$$y^* = \left(\frac{S_k}{n + g + \delta} \right)^{\frac{a}{1-a}}$$

Thus, the explanation and equations explain us the causes for the difference in the growth levels of different countries. The countries that spend highly on physical capital, have better technology and

Notes

spend a high proportion of time in accumulating new skills are relatively richer than those which do not give due importance to investment in physical and human capital.



Notes

knowledge capital is the means to attain human capital which in turn is the means to increase the rate of growth.

11.2 Endogenous Technology, Increasing Returns and Monopolistic Competition

After understanding the implications for economic growth, of expanding the notion of capital to include human capital, the effects of human capital on economic growth were explained. Now let us discuss the nature of human capital and the way it is created. No doubt, human capital will aid the growth process. But the model will help us to quantify the relation between growth and human capital.

Let us look at a standard Cobb-Douglas production function in the human capital augmented neo-classical-growth model.

$$y = A e^{nt} K^a L^{1-a}$$

In such a model, savings will create growth for a while but it will not be steady and sustaining growth. As the ratio of labour to capital would rise, marginal product of capital will fall and the economy would revert back to the same level of growth. Growth in income per worker will continue to take place and grow and which is an indicator of increase in the level of human capital. Traditional neo-classical theory takes m as an exogenous variable but endogenous growth theory explains how is the value of n determined.



Task

How do people accumulate human capital?

AK Model of Endogenous Growth: AK model of endogenous growth was presented by **Sergio Rebelo** through his article titled 'Long Run Policy Analysis and Long Run Growth' which was published in 1991. It is based on the work done by Romer and Lucas. The basic equation of the model is :

$$Y = AK$$

Where A is symbolic of factors affecting technology and K includes physical as well as human capital. The model rejects that proposition of diminishing returns. It claims that externalities or spillovers and increasing quality and variety of intermediate inputs do help to avoid diminishing returns.

Basic equation of of AK model is :

$$\dot{K}^* = sy - \delta k$$

Dividing both sides by K ,

$$\frac{\dot{K}}{K} = s \frac{y}{K} - \delta$$

On substituting $\Delta K = y$ in the equation

$$\frac{\Delta K}{K} = sA - \delta$$

$$Y = \Delta K$$

Taking natural logarithms.

$$\ln Y = \ln A - \ln k$$

Differentiating it w.r.t

$$\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K}$$

Therefore, growth rate of output is equal to growth rate of investment.

Generally speaking, lesser importance has been given to technology because endogenous growth theory admits that technology does not explain much of the growth. Initially technology was given a high importance. But then some economists claimed that there is not much need to understand technology as it is a very small part of the contribution to growth process. They feel that it is so small that it can even be ignored. But it is not logical. Solow model as well as empirical evidence shows that even if capital formation directly contributes to growth, without technological advancement, growth would stop. It is so because it is technology that causes investment in the capital and indirectly causes all the growth. It is technological advancement that makes it possible to get increasing returns from all relevant inputs.

Technology connotes the way in which inputs are converted into output. Technology can be taken as a factor which stimulates the productivity of all factors of production. In a Cobb-Douglas production function, technology can be shown as :

$$Y = K^a (AL)^{1-a}, \text{ where } A \text{ is an index of technology.}$$

Paul Romer's views on technology and its impact on growth process :

Romer published his two papers in the year 1986 and 1990 in which he presented a way of modeling ideas as an engine of growth. Romer claimed that new ideas are non-rivalrous good and hence produce increasing returns to scale. He further claimed that increasing returns to scale with explicit presence of research can prevail if and only if there is imperfect competition in the market.

Most of the economic goods are non rivalrous in nature. This means that if good X is used by someone, everyone else is excluded from using same good X. unlike economic goods, ideas are non rivalrous in nature. Once an idea is created, it is available for all. But ideas can be excludable particularly if they carry copyrights or patent rights. In such cases, the creator of the ideas can charge a price for their ideas. Goods that are excludable benefit their producers in the form of higher incomes. Goods that are non-excludable benefit the whole economy by producing externalities and spill overs.

Rivalrous goods need to be produced as many times as it is consumed. If say a book is sold once, we need to produce another book for next customer. But non excludable goods can be consumed by unlimited number of people once they are produced. Say for example, a road, it can be used by thousands of people in one day but do not have to be created again and again. It implies that non excludable goods have a fixed cost and zero marginal cost. It takes effort to create them in first go and then it can be used many times.



Did u know? The cost of knowledge capital is fixed and subsequent units can be produced under constant returns to scale.

Notes

Such cost structure implies increasing returns to scale and imperfect competition. Since, the units after the first unit are getting produced under constant returns to scale then the entire production takes place at increasing returns to scale therefore, AC curve is downward sloping.

Therefore, we have understood following facts :

- (a) Ideas are non-rivalrous in nature;
- (b) They produce increasing returns to scale;
- (c) Non-rivalrous goods have a fixed cost of production and zero marginal cost. It applies to ideas as well.

It implies that if we attain producer equilibrium by equalizing MR and MC, price will always be less than AC and thus losses. When someone produces a useful, idea, he is given a patent or a copyright on the same if he applies for it. It gives him monopoly powers and he is able to reap profits from their ideas and inventions.



Caution Perfect competition would not sustain time dependent production functions for technical change because the firms would operate at a minimum efficiency level and it is not beneficial to increase the size of the firm.

Romer's Model of Endogenous Technological Change:

Romer assumed production function to be equivalent to:

$Y = K^a (AL)^{1-a}$ where L is labour; A is stock of ideas; a lies between 0 and 1; K is capital. If L and K are doubled, then output will double. If L, K and A is doubled then output will be more than doubled. Hence, A causes increasing returns to scale.

In Romer's model, capital accumulates as people save at a constant rate and it is similar to that of Solow model. There is also depreciation of capital.

Labour grows at a constant rate n . Romer introduced an equation that describes the accumulation of ideas. In the neo-classical model, A is the productivity term and increases exogenously at a constant rate. But in Romer's model the growth of A is taken as endogenous. Given the stock of knowledge accumulated till a time period t , $\Delta t = dA/dt$ is the number of new ideas produced.

In Romer's model if a particular fraction of the population is engaged in production of ideas i.e. R and D, then the model predicts that all growth is due to technological progress. Rate of growth of output will be equal to rate of capital formation and rate of technical progress. Along the balanced growth path, A will grow at a constant rate.

There are three sectors in Romer's model:

- (a) A Final Goods Sector;
- (b) An Intermediate Goods Sector;
- (c) Research and Development Sector.

In the economy, the R and D sector produces ideas, and sells the right to use these ideas to intermediate sector which in turn uses these ideas to produce capital goods. These capital goods are sold to final goods sector which produces consumer goods from it. The intermediate sector is monopolist and there is imperfection in this sector.

Introduction of monopolistic competition has made us realize that firms spend on creating ideas, earn monopoly rights on them; and then charge monopoly rents for them.

Self-Assessment**Notes**

1. Fill in the blanks:
 - (i) Growth rate of almost all economies of the world has been faster than
 - (ii) The model maintain solow's assumption of to the capital as a factor of production.
 - (iii) Knowledge capital is the means to attain human capital which in turn is the means to increase the
 - (iv) Ak model of endogenous growth was presented by
 - (v) Most of the economic goods are in nature

11.3 Some Issues in Endogenous Growth Theory

A major issue in the endogenous growth theory is about implications of Endogenous Growth Models from developing countries. It has been claimed for a long time that countries are required to increase their savings to give a push to the rate of economic growth. Under this background we can understand the implications of Endogenous Growth theories for developing countries.

First of all, Economists like Arthur Lewis and Rostow emphasized on increasing the rate of savings substantially. The Endogenous Growth Theory gives a great emphasis on accumulation of human capital even more than physical capital. They laid a great stress on knowledge capital. Secondly, since knowledge capital can be acquired by transfer of technology, developing nations would do well if they open up their economies for developed economies. It would increase the sharing of technology. Thirdly, the theory also recognizes the role of policies and government in promoting the rate of knowledge capital and thereby human capital formation. Government need to formulate favourable policies to promote the rate of human capital formation. And most importantly, the theory also suggests that automatic convergence in the growth rate does not occur and therefore a planned effort is required. Rather it explained logically that in spite of same saving rate, population we can see different countries growing at different rates due to difference in their level of human capital. And hence, government needs to formulate favourable policies to promote the rate of human capital formation. It is a way to break vicious circle of poverty.

Endogenous theory is called new growth theory because it came into picture later than exogenous growth theory. Endogenous theory is modern as it explains technology as an endogenous variable. Exogenous theory was outdated with the introduction of endogenous growth models. The idea of the fact that technology is and must be incorporated as an endogenous variable in growth models was also recognized by the economists like Marx and Schumpeter.

Exogenous theories claimed that economies converge towards equal growth rates but endogenous theory expanded the notion of capital to include human capital and claimed that different countries diverge from each other depending upon the level of human capital formation.

Self Assessment

2. State whether the following statements are 'true' or 'false'.
 - (i) Solow growth model stated that if initial conditions were similar in different countries, eventually the levels of income of these countries would converge.
 - (ii) According to mankiw, Romer and weil people can not sacrifice their present consumption to accumulate human capital.
 - (iii) 'Long Run Policy Analysis and Long Run Growth both article was published in 1991.
 - (iv) Technology can be taken as a factor which stimulates the productivity of all factory of production.
 - (v) Romer published his two papers in the year 1985 and 1989 in which he presented a way of modeling idea as an engine of growth.

Notes

11.4 Summary

- Solow growth model stated that if initial conditions were similar in different countries, eventually the levels of income of these countries would converge.
- According to Mankiw, Romer and Weil people sacrifice their present consumption to accumulate human capital.
- Solow model as well as empirical evidence shows that even if capital formation directly contributes to growth, without technological advancement, growth would stop.
- A major issue in the endogenous growth theory is about implications of Endogenous Growth Models from developing countries.
- Endogenous theory is called new growth theory because it came into picture later than exogenous growth theory.

11.5 Key-Words

- accumulate : to gradually get more and more of something over a period of time.
- enhance : to increase or further improve the good quality, value or status of something.
- rival : a person, company, or thing that competes with another in sport business etc.
- external : connected with or situated on the outside of something.

11.6 Review Questions

1. In what way are the models incorporating human capital different from the standard neo-classical models?
2. Explain why the production of ideas involves imperfect competition?
3. Why do diminishing returns to capital not set in the AK model of production?
4. What are the implications of endogenous growth models for developing countries?
5. What is technology and how does it produce increasing returns?

Answers: Self-Assessment

1. (i) population growth (ii) diminishing returns
(iii) rate of growth (iv) Sergio Rebelo (v) non-rivalrous
2. (i) T (ii) F (iii) T (iv) T
(v) F

11.7 Further Readings



Books

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.

Unit 12: Stochastic Growth Models-Business Cycle Theory

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Objectives

After reading this unit students will be able to:

- Know about the growth under uncertainty.
- Understand the Brock Mirman Model.
- Describe the real business cycle model.

Introduction

The word stochastic is derived from a Greek word “stochastikos” which means skilled at hitting targets. This unit explains how to make decisions over time in an environment of uncertainty. In this unit, some models have been explained that deal with the situation in which the decision-maker has to predict future value of variables in the presence of some random external shocks in the economy. These shocks can create business cycles and fluctuations in the process of growth. The unit explains some basic concepts regarding how to deal with uncertainty. It explains some models that explain decision-making in the presence of uncertainty. An effort has been made to explain why an economy experiences fluctuations.

12.1 Growth Under Uncertainty

We shall start with an economy with one commodity and no external shocks with an assumption that this commodity can be used either for consumption or investment. Let us assume that in our one commodity economy, in any given period t , output y_t is divided into consumption for the next period $c(t+1)$ and capital for the next period k_{t+1} . The production function is:

$$y_t = F(k_t)$$

For simplification, let us not assume that labour is anywhere in production process so that the basic equation of motion is given by:

$$k_{t+1} = f(k_t) - c_t + 1$$

On substituting production function in the above equation, we get:

$$y_t = c_t + 1 + k_{t+1}$$

Notes

If consumption in the next period is a function of output in the previous period then it is indirectly a function of capital in the previous period.

It implies

$$c_{t+1} = f(y_t), \text{ and}$$

$$y_t = F(k_t)$$

Therefore,

$$c_{t+1} = c(f(k_t))$$

or more generally

$$c_{t+1} = f(k_t)$$

If we assume that the function is continuous and differentiable twice such that :

$$f > 0, k > 0, f(0) = 0$$

$$f' > 0, \text{ and } f'' < 0$$

$$f''(0) = \alpha', f'(\alpha') = 0$$

Then the economy is in steady equilibrium if $k_t + 1 = k_t$ for all time periods. T is a unique equilibrium.

The David Cass and Tjalling Kopsman formulation can be explained as follows:

If we assume that the society has a utility function equal to $U(c_t)$ and the stream of utility accruing to society $\{U_1, U_2, U_3, \dots, U_t\}$ then the total utility can be derived by computing the present discounted value of the utility stream which is equal to :

$$U = U_0 + \frac{U_1}{(1+\alpha')} + \frac{U_2}{(1+\alpha')^2} \quad \dots (1)$$

Where α' is the rate of time preference or discount rate. If we denote $1/(1+\alpha')$ by a , and call a as discount factor, then

$$U = U_0 + aU_1 + a^2U_2 \quad \dots (2)$$

Hence, the first reason put forward for inculcating the discounting of future utility is simple that the social planner has a preference for present utility to future utility.

Cass Koopman's Model assumes that there is a representative agent of the society who aims at maximizing an inter-temporal utility function:

$$U = U_0 + aU_1 + a^2U_2 \quad \dots (3)$$

Where a is the discount factor and $0 < a < 1$

The utility function given above is additively separable over time.

12.1.1 Economic Growth under Uncertainty

(a) When optimization is not explicitly introduced into the model:

Let us not introduce optimization explicitly into our model. Let production function be equal to $y_t = f(k_t, \varepsilon_t)$ where ε is random variable. This has been brought into the picture to bring about the concept of uncertainty into the model. Such a production function implies that the output in an economy is dependent not only on capital stock but also the economic and market conditions which are quite uncertain. There are manmade, economical and natural uncertainties. Man made uncertainties like civil wars, bomb blast etc. Natural factors also cause natural calamities and affect mainly supply side. Therefore, they have an impact on production function. There is

Notes

also uncertainty in government policies. If we take an assumption that all these types of uncertainties are identically and independently distributed over different time periods and economic activities, then equation describing capital formation in the next period can be written as:

$$k_{t+1} = f(k_t, \varepsilon_t) - c(k_t, \varepsilon_t)$$

It implies that uncertainty in the market is affecting not only production but also consumption.

We can write this equation as:

$$k_{t+1} = h(k_t + 1, \varepsilon_t)$$

This is called Markov process. It is an example of stochastic performance.

- (b) When optimization is explicitly introduced into the Model:



Did u know? Sudden fluctuations in demand, cyclical fluctuations are the sources of economic uncertainty.

12.2 Brock Mirman Model

Brock and Mirman presented two papers in 1970s. In the first paper they explained stochastic optimization with discounting, i.e. inculcated element of uncertainty in Cass-Koopmans Model; and in the second paper they introduced the element of uncertainty without discounting. In other words, they introduced uncertainty in the Ramsey model. Given below is the explanation of Stochastic optimization with discounting.

Assumptions

- Decisions are being taken explicitly by the individuals i.e. consumer is the planner.
- The goal of the planner is optimization of expected utility.
- Since initial values of capital stock and consumption levels depend on capital stock and consumption in the previous period, therefore, the process of optimization is dynamic.
- There are two time periods.
- Consumer has a given endowment of wealth equal to w_1 which he can invest on two assets x and y . x gives him assured return of r_1 and y gives him a risky return of r_2 .
- The consumer spreads his wealth among two assets in a ratio of a and $1-a$.
- When there are two time periods:

On the basis of above assumptions, the model states that the consumer's second period wealth will be equal to his second period consumption. It makes consumer budget equation equivalent to:

$$w_2 = c_2 = (w_1 - c_1)[r_1 a + r_2(1-a)] = (w_1 - c_1)r$$

In the above equation $r = r_1 + r_2(1-a)$

The important point to be noted is that as per above equation the consumer's return on wealth is uncertain and so is his future consumption. If we denote future consumption by c , then the consumer will have a utility function

Notes

$U\{c_1, c_2\} = u(c_1) + \alpha' u(c_2)$ where α' is the discount factor. Let $A_1(w_1)$ be the maximum utility that consumer can get if he has wealth w_1 in time period t_1 . It implies

$$A_1(w_1) = \max u(c_1) + \alpha' Eu[(w_1 - c_1)r]$$



Caution For maxima, first derivative has to be zero and second must be negative.

Hence, on differentiating the above equation with respect to time, we get first order conditions to be equal to:

$$u'(c_1) = \alpha Eu'(c_2)r$$

$$Eu'(c_2)\{r_1 - r_2\} = 0$$

- (ii) When it is a situation of optimization over T time period:

In such a situation there will be $(c_1, c_2, c_3, \dots, c_t)$ will be stream of consumption that is random. The objective of the consumer is to maximize his utility from this consumption stream. In terms of an equation, it can be presented as follows :

$$U(c_1, c_2, \dots, c_t) = \sum \alpha' t Eu(c_1)$$

If at time t , consumer has a wealth w_t , and invests in the risky asset, his wealth in the period $t + 1$ will be equal to :

$$w_{t+1} = [w_t - c_t]r$$

Where is $r = r_1 + r_2(1 - a)$

In such a situation, optimization problem can be solved by dynamic programming by breaking the problem into two consequent time periods.

Suppose in the period $t - 1$ the consumer has wealth that is equal to w_{t-1} the utility that he can get is equal to :

$$A_{t-1}(w_{t-1}) = \max u(c_{t-1}) + \alpha Eu[(w_{t-1} - c_{t-1})r]$$

Now we can get first order condition by differentiating the above equation with respect to time.

$$u'(c_{t-1}) = \alpha' Eu(c_t)r$$

$$Eu'(c_t)\{r_1 - r_2\} = 0$$

Now we go back to one period back i.e. $t - 2$. In this period, if the consumer chooses $(c_t - 2, x_t - 2)$ then in the period $t - 1$, he will have a wealth which is equal to:

$$w_t - 1 = [w_{t-2} - c_{t-2}]r$$

He can derive expected utility of $A_{t-1}(w_t - 1)$. In such a situation, his maximization problem in $t - 2$ will be expressed by the equation:

$$A_{t-2}(w_t - 2) = \max u(c_{t-2}) + \alpha Eu[(w_t - 2 - c_{t-2})r]$$

Now we can get first order condition by differentiating the above equation with respect to time as we did earlier with only difference that there the time was $t - 1$ and here it is $t - 2$.

$$u'(c_{t-2}) = \alpha EA'(w_t - 1)r$$

$$EA'(w_1 - 1)\{r_1 - r_2\} = 0$$

Similarly, we can get the first order conditions for all time periods.

Self-Assessment

1. Fill in the blanks:
 - (i) The word stochastic is derived from a Greek word which means skilled at hitting targets.
 - (ii) An effort has been made to explain why an experiences fluctuations.
 - (iii) There are manmade, economical and uncertainties.
 - (iv) Brock and Mirman presented papers in 1970.
 - (v) The objective of the consumer is to maximise his utility from this consumption stream.

12.3 The Real Business Cycle Model

Real Business Cycle model is technically an explanation of Brock-Mirman Model. They explained, "What happens under uncertainty" and Real Business Cycle explains, "Why does it happen so?". It tried to explain the reasons for fluctuations in economic activity at macro level.

Real Business Cycle model Makes two types of propositions:

- (a) It says that long-term growth and short-term fluctuations in economic activity are studied separately but for both of them same reasons are responsible. The theory uses the word fluctuations and not cycles as the latter conveys as if it occurs regularly which might not be true.
- (b) The word 'real' in the Real Business Cycle Model suggests that this theory like classical economists considers money to be veil and plays down the role of monetary forces. In their opinion money plays a neutral role and fluctuations are brought about by real factors like investment, demand, supply etc.

The Real Business Cycle Model criticizes on Keynesian approach that it gives too much emphasis on the aggregate demand. This theory gives a greater emphasis on supply side and therefore, is sometimes also called 'New-Classical'.

However, there can be many types of external shocks. These shocks can originate on either demand side or supply side. These shocks may be caused even by monetary and fiscal policy of the government. There are different types of productivity shocks:

- (a) Development of new techniques;
- (b) New management practices;
- (c) Bumper crop or crop failure;
- (d) New Suppliers coming from external economy etc.

The Real Business Cycle Model explains productivity shocks and the extension as well as impact of these shocks on other variables in the economy.

The Real Business Cycle Model is built upon Brock-Mirman Model of the type in which discounting is present. The model explains a decision regarding labour and leisure where it is assumed that leisure also gives utility.



Notes

Focus of The Real Business Cycle Model is on productivity shocks.

Notes

The structure of the model is similar to that of optimization under uncertainty.

We need to maximize a utility function like $E \left[\sum_{j=1}^{\infty} \alpha^j u(c_t + j, l_t + j) \right]$. Here c and l are household's and leisure activities.

Each household has access to a given technology (as each household is playing dual role in the economy. Each household is a firm as well.

$$y_t = z_t f(L_t^d, K_t^d)$$

When Z = random variable depicting technology L and K denote labour and capital supplied in the time period t .

$$L = 1 - l \text{ where } l \text{ is leisure}$$

therefore, the Budget constraint is :

$$c_t + K_{t+1} = Z_t f(L_t^d, K_t^d) + (1 - \delta)K_t - w(L_t^d - L_t) - r(K_t^d - K_t)$$

Where

w = wage rate

r = rate of interest

This equation is explained one should use dynamic programming and a constrained optimization increase. It also explains shocks - how they are generated in the economy.



Task

What does RBC theory have to say about the cause of the fluctuations?

Self-Assessment

2. Multiple choice questions:

Choose the correct option

- (i) Real business cycle model is technically an explanation of model.
 - (a) Brock model
 - (b) Mirman model
 - (c) Brock-Mirman model
 - (d) Solow model
- (ii) model criticises on Keynesian approach that it gives too much emphasis on the aggregate demand.
 - (a) The real business cycle
 - (b) The real business cycle
 - (c) Solow model
 - (d) Brock model
- (iii) The structure of the model is similar to that of optimization under
 - (a) certainty
 - (b) uncertainty
 - (c) similar
 - (d) none of these

12.4 Summary

- The word stochastic is derived from a Greek word "stochastikos" which means skilled at hitting targets.
- We shall start with an economy with one commodity and no external shocks with an assumption that this commodity can be used either for consumption or investment.
- If consumption in the next period is a function of output in the previous period then it is indirectly a function of capital in the previous period.

- Brock and Mirman presented two papers in 1970s. In the first paper they explained stochastic optimization with discounting, i.e. inculcated element of uncertainty in Cass-Koopsman Model; and in the second paper they introduced the element of uncertainty without discounting.
- Real Business Cycle model is technically an explanation of Brock-Mirman Model.
- The Real Business Cycle Model criticizes on Keynesian approach that it gives too much emphasis on the aggregate demand. This theory gives a greater emphasis on supply side and therefore, is sometimes also called 'New-Classical'.

Notes**12.5 Key-Words**

- **Economy** : the relationship between production trade and the supply of money in a particular country or region.
- **Fluctuation** : Process to change frequently in size, amount, quality, etc, especially from one extreme to another.
- **Commodity** : a product or a raw material that can be bought and sold, especially between countries.

12.6 Review Questions

1. How does the presence of uncertainty affect the basic one-goal growth model?
2. Describe the basic structure of Brock-Mirman model.
3. What does RBC theory has to say about the cause of the fluctuations?
4. What is RBC theory called "New classical"?
5. In what way does the RBC theory build upon the Brock-Mirman Model?

Answers: Self-Assessment

1. (i) stochastikos (ii) economy (iii) natural (iv) two
(v) consumer
2. (i) (c) (ii) (a) (iii) (b)

12.7 Further Readings**Books**

1. A.P. Thirlwall, *The Economics of Growth and Development*, Vol-I. Caterloury, UK, 1995.
2. Michael P. Todaro, *Economic Development*, Pearson Education India, 2002.
3. J.S.L. McCombie, Roger William Vickerman, *Growth and Economic Development*, Edward Elgar Publishing.