# MACROECONOMICS

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## Summary

This chapter presents a survey of the growth literature based on the concept of accumulation of human capital. The presentation of this literature is guided by some key empirical observations on economic growth, and special emphasis is placed on discussing the capability of these models to explain some of these observations. One of the most puzzling observations is the variation across countries in the level of income per capita and in its rate of growth. In this chapter, the following explanations for this variation are assessed. First, differences in initial conditions are considered. It is well known that countries have different natural conditions and different natural resources. A model of physical and human capital accumulation is used to study the growth consequences of starting with different initial conditions. Second, an alternative explanation relies upon differences on economic policies. A model with income taxation is used to study the growth effects of different taxation policies. Third, the role of expectations is evaluated. This third explanation emphasizes the importance of issues such as coordination, optimism, etc., in the process of economic growth.

## 1. Introduction

Macroeconomics is the branch of economics in which observed aggregate economic variables are interpreted as the result of decisions taken by economic agents that face a set of physical and market restrictions. One of the main objectives in macroeconomics is to investigate how aggregate variables would change after changes in these restrictions. Since government policies define an important part of the restrictions faced by economic agents, macroeconomists have devoted special attention to analyze the consequences of alternative public policies on aggregate economic variables.

The context in which macroeconomists tried to give answers to these questions has experienced substantial changes since the early decades of the twentieth century, when macroeconomics became an independent and well-defined discipline within economic theory. The evolution of the theoretical context was due, mainly, to the advances made in two different fronts. First, in the late 1950s two important developments namely, applications of optimal control theory, and the theory of dynamic programming, represented a drastic change in macroeconomic thinking. These two developments, which provide a method to solve a wide class of dynamic optimization problems, triggered an explosion of research activity in macroeconomic problems with an important dynamic ingredient. Second, there was a significant increase both in the quantity and the quality of data sets available for macroeconomic research. The construction of new techniques of empirical analysis, along with data availability, introduced a turn in the macroeconomics research agenda.

The 1930s influenced by the devastating effects of the Great Depression, were dominated by the view that a market economy, left for itself against its own forces, cannot recover from a depression, and that government intervention is indispensable to restore the level of economic activity. These ideas, presented by John Maynard Keynes in his *General Theory of Employment, Interest and Money*, were organized around the existence of certain rigidities in the labor market, which can yield a market equilibrium with unemployment. Keynes' theory was mainly a short-run theory, and therefore, gave little insight on how the system would evolve over time. The main conclusion reached by Keynesian macroeconomists was that the government should play an active role in the management of the economy by choosing appropriately the level of government expenditure. The so called stabilization policies became thus a common practice worldwide. In this static model, however, the effects of fiscal policies on consumption and investment decisions, taken by private economic agents, were not well specified. The short-run nature of the Keynesian model, along with the assumed stability of the consumption function, leaves aside important dynamic general equilibrium effects.

The sustained increase in economic activity, initiated after World War II, shifted the macroeconomists' interest to growth theory. Economic growth is a dynamic phenomenon, and consequently, it must be analyzed in a theoretical setting in which economic agents face an intertemporal decision problem. Since growth theory is a theory of the long-run, time is modeled as an exogenous variable evolving from an initial period to infinity. One of the most important contributions of the theory of growth in the 1950s is the method of growth accounting, which consists in decomposing the growth rate of aggregate output into contributions from the growth of physical capital, labor, and technology. Since technology as productive input, is not directly observable, the exercise of growth accounting allow us to compute the percentage of growth in output that can not be explained by growth in physical capital and labor. The result of this accounting exercise yields a surprisingly high value for the percentage of growth due to increases in the level of technology. For example, in the U.S. economy, for the period 1947-1973, a 42.7% of the growth rate in Gross Domestic Product (GDP) was due to the accumulation of physical capital, a 23.7% is explained by changes in the level of employment, and a 33.6% represents changes in the level of technology.

A theory of growth is a set of assumptions on the relationship between the level of inputs and the level of production, and on how inputs evolve over time. The first models of economic growth, developed in the 1950s and 1960s, started by assuming constant returns to scale production function, and placed the emphasis in physical capital accumulation. Both labor and technological change were assumed to follow exogenous paths with constant rates of growth. Changes in the level of physical capital were modeled as the result of investment decisions taken by rational agents seeking to maximize the discounted lifetime utility. In these models, the assumption of constant returns to scale on capital and labor implies that the long-run rate of growth of per capita income is uniquely given by the rate of technological change. Accordingly, as this latter rate is exogenously given, the model leaves the rate of economic growth unexplained. The main aim in the theories of economic growth developed in the 1980s and 1990s is to provide an explanation for the evolution of technology over time. That is, the new growth theories endogenize technical change by adding a new productive sector to the model. A strand of this new literature has focused on the economics of knowledge, where knowledge is understood as the level of productive ideas available in the economy. One of the main concerns is thus to understand how new ideas are used in the economy, and how researchers produce new knowledge in laboratories. A second strand of this new literature has focused on the role human capital, that is, on how schooling decisions increase the level of human capital embodied in the labor force. The increasing importance of the schooling sector, and the fact that the stock of human capital is about three times as large as the stock of physical capital, make this literature on human capital an appealing theoretical approach to address questions related to economic growth and individual investment decisions. This chapter provides a survey of endogenous growth models with human capital accumulation and special emphasis will be placed on showing how to use these models to understand the observed disparities in income levels and growth rates across countries. Growth models with human capital accumulation are used in order to assess three alternative explanations for these disparities. First, the effects of initial conditions on long-run growth are studied. Second, a model with taxes on capital and labor income is presented, and its effects on the rate of economic growth are analyzed. Third, we study the role of agent's expectations on the pattern of growth. The common ingredient in all these models is that human capital accumulation is the engine of long-run growth.

## 2. Stylized Facts on Economic Growth

Modern theory of economic growth has been constructed on a set of stylized facts. These facts consist of a list of empirical regularities, which provide a description of the process of economic growth, and of the relationship between key economic variables over time. The British professor Nicholas Kaldor was the first economist in offering a systematic treatment of these observations.

The main stylized facts on economic growth are the following.

1. There are enormous variations in per capita income across countries.
2. There are wide differences in the rate of growth of productivity across countries.
3. Output per worker shows continuing growth with no tendency for a falling rate of growth of productivity.
4. Capital per worker shows continuing growth.

5. The rate of return on capital is steady.
6. Labor and capital receive constant shares of total income.
7. The capital-output ratio is steady.
8. In cross section, the mean growth rate shows no variation with the level of per capita income.

Stylized facts 1 and 2 have been extensively documented in the recent literature. We simply present here some examples illustrating these two facts. In order to compare income levels across countries, which are originally measured in different currencies, economists use a purchasing power parity-adjusted exchange rate. This rate is designed to measure the actual value of a currency in terms of its ability to purchase similar products. Using this rate to compare the real Gross Domestic Product (GDP) across countries, we find that there exist surprising differences in per capita income across countries. In order to have an idea of the magnitude of these differences, we present here some examples. U.S. GDP per capita in 1990 (measured in 1985 dollars) was around $18,073; Japanese GDP was $14,317, and West German GDP was $14,331. These countries were in the group of the richest countries in world. By contrast, GDP in 1990 in China was $1,324, Indian GDP was $1,263, and in Uganda $554. These countries were among the poorest in the world. This selected group of countries illustrates the high disparity in income levels across countries. This disparity, however, is a relatively recent phenomenon. Before the Industrial Revolution, income levels in most economies where slightly above the subsistence level, and consequently, the variance of the world distribution of income was considerably lower. Thus, the current income distribution must be interpreted as the result of differences in the rate of growth since the Industrial Revolution. Indeed, economic growth, such as it is understood nowadays is a recent phenomenon. Growth rates in the range of 2-5 per cent, observed in some countries during the last century, do not have a precedent in the history of economic growth. If we concentrate on the twentieth century, for which we have a broader and more reliable data set, two main features are observed. First, there is a huge disparity in growth rates across countries. Second, on average, poor countries do not grow faster than rich countries. Thus, neither convergence in income levels nor in growth rates is observed in the data.

Remaining stylized facts have been also well documented from measured data. Some recent estimates of the capital share seem to have found a slight decline in this share over time (which could invalidate fact 6). As an example, the estimated share in the U.S. for the period 1899-1919 is 35%, for 1919-1953 is 25%, and for the period 1929-1953 is a 29%. However, the issue of estimating capital shares is still subject to controversies, mainly because of the ambiguity in the definition of capital income, and for the arbitrary methods to impute housing income. The constancy of the income share continues to be an accepted proposition in the theory of economic growth. Fact 7, the constancy of the capital-output ratio, has also been subject to a continuous validation. Whereas in high-income countries there are no doubts about the constancy of this ratio, in low-income countries it has been subject to some remarks. The capital-output ratio is also constant across countries. The estimated ratio in a group of developed countries gives a value of 3.4.

Overall, these facts constitute our basic body of knowledge on the empirics of growth.

The goal of growth theories is to provide explanations for these facts.

## 3. A Basic Model of Physical and Human Capital Accumulation

Our basic framework is the standard optimal growth model with an infinite horizon and a representative agent. For analytical simplicity, population is normalized to one and the rate of population growth is assumed to be zero. In order to highlight the main dynamic properties of the model, we start by studying an economy without distortions, which allow us to analyze the competitive equilibrium allocation by solving the planner's problem. Preferences over consumption streams, $\{c(t)\}_{t=0}^{\infty}$ are given by

$$\int_0^\infty e^{-\rho t} \frac{c(t)^{1-\sigma}-1}{1-\sigma} dt, \qquad (1)$$

where $\rho > 0$ is the discount rate, and $\sigma > 0$ is the inverse of the elasticity of intertemporal substitution for consumption.

This representative agent owns a stock of physical capital, $k(t)$, and has an endowment of one unit of time per period. If the fraction of time devoted to work is denoted by $u(t)$, then the efficiency units of labor supplied is $u(t)h(t)$, where $h(t)$ denotes the level of human capital or skills of the representative agent at time t. There are two production sectors in this economy. The output sector produces an aggregate good, $y(t)$, using a standard constant returns to scale, Cobb-Douglas production function,

$$y(t) = Ak(t)^\alpha \left(u(t)h(t)\right)^{1-\alpha}, \qquad (2)$$

where $A > 0$ and $0 < \alpha < 1$ are parameters. Parameter $\alpha$ is the capital share, which has been shown to be constant both over time and across countries. Output in this sector can be either consumed, $c(t)$, or invested as physical capital, $i(t)$. Denoting the depreciation rate for physical capital by $\delta > 0$, the law of motion for $k(t)$ is given by,

$$\dot{k}(t) = i(t) - \delta k(t). \qquad (3)$$

The representative agent may also devote resources to increase her/his level of human capital. In order to simplify the presentation, we will assume by now that the educational technology uses time as the unique input. This assumption is relaxed in the next sections, and more general technologies will be assumed for human capital production. We also impose in this section that the technology to produce new human capital has constant returns to scale. Therefore, the law of motion for human capital is

$$\dot{h}(t) = B\left(1-u(t)h(t)\right) \qquad (4)$$

where $B > 0$ is a parameter, and 1 - $u(t)$ is time allocated to the educational sector. For simplicity, we also assume a zero depreciation rate for human capital. This assumption does not affect the results presented in this chapter.

An optimal allocation for this economy is a set of paths $\{k(t),h(t),c(t),u(t)\}$ that maximize lifetime utility, (1), subject to (2), (3), (4), and initial conditions $k(0)$ and $h(0)$. This maximization problem is a standard optimal control problem. The solution method makes use of optimal control theory, which was developed in the late 1950s, and is now standard in many areas as game theory, industrial organization, etc. For the reader not introduced to these techniques, we present in the Appendix the derivation of the necessary and sufficient conditions for a maximum. Shortly, first-order conditions establish that the marginal value of time allocated to the output sector, and to the human capital sector must be equalized, i.e.,

$$(1-\alpha)Ak(t)^{\alpha}\left(u(t)h(t)\right)^{-\alpha}=q(t)B \tag{5}$$

where $q(t)$ is the price of human capital in units of the aggregate good. The allocation of current income between consumption and physical capital investment must satisfy,

$$\sigma\frac{\dot{c}(t)}{c(t)}+\rho=\alpha\, Ak(t)^{\alpha-1}\left(u(t)h(t)\right)^{1-\alpha}-\delta\,. \tag{6}$$

Finally, the relative price of human capital must satisfy the following arbitrage condition,

$$\frac{\dot{q}(t)}{q(t)}=-B+\alpha\, Ak(t)^{\alpha-1}\left(u(t)h(t)\right)^{1-\alpha}-\delta\,. \tag{7}$$

It is of interest to note that under our assumptions on preferences and technologies the first-order conditions, together with the transversality conditions, complete the set of sufficient conditions for an optimal solution. This can be shown from the concavity of the utility function, and from the convexity of the restriction set defined by the two concave production functions.

Our goal now is to study the dynamic properties of the equilibrium path, both in the short as in the long run. We are primarily interested in the determination of the rate of economic growth, and in finding out the effects that preferences and technology parameters exert on this rate. In contrast to the neoclassical growth model, the behavior of the economy along the transitional period toward the long-run equilibrium may have important consequences on long-run per capita income in our model. We devote part of this section to study two important aspects of the transitional dynamics: the speed of convergence to the long-run equilibrium, and the sensitivity of the investment rate in human capital to wealth shocks. These two aspects of the transitional dynamics are of paramount importance when evaluating the consequences of public policies as taxes or other fiscal policies.

A *Balanced Growth Path* is a solution to the planner's problem along which consumption and both kinds of capital grow at a constant rate, and time allocation variables remain constant. Imposing balanced growth conditions,

$\frac{\dot{k}(t)}{k(t)} = \frac{\dot{h}(t)}{h(t)} = \frac{\dot{c}(t)}{c(t)} = g$ and $\frac{\dot{u}(t)}{u(t)} = 0$, on the system of first-order conditions we obtain,

$$\alpha A\left(\frac{k}{h}\right)^{\alpha-1} u^{1-\alpha} - \delta = \rho + \sigma g, \tag{8}$$

$$\alpha A\left(\frac{k}{h}\right)^{\alpha-1} u^{1-\alpha} - \delta = B, \tag{9}$$

$$A\left(\frac{k}{h}\right)^{\alpha-1} u^{1-\alpha} - \delta = \frac{c}{k} + g, \tag{10}$$

$$g = B(1-u). \tag{11}$$

This system can be solved for the four unknowns that characterize a balanced growth equilibrium, that is, the growth rate, $g$, labor supply, $u$, the physical-to-human capital ratio, $\frac{k}{h}$, and the consumption-to-human capital ration, $\frac{c}{h}$. The existence of a balanced growth equilibrium imposes that the net rate of return on physical capital is constant at $\rho + \sigma g$.

Since we will focus on long-run equilibria with positive growth, $g > 0$, it follows from the law of motion for human capital that $0 < u^* < 1$. Moreover, from Eq. (8) and (9) we obtain the rate of economic growth along a balanced growth path as a simple function of the parameters describing agent's preferences and the technology in the human capital sector,

$$g = \frac{B - \rho}{\sigma}. \tag{12}$$

There are several features in this balanced growth path that make the model distinctive respect to the neoclassical growth model. First, the rate of economic growth is endogenously determined, and therefore is bound to be affected by public policies. Hence, this model can be an appropriate framework to understand the variance in growth rates across countries. Second, the balanced growth path, as we showed above, does not determine the levels for $k(t)$, $h(t)$ and $c(t)$, only the ratios $\frac{k}{h}$ and $\frac{c}{h}$ are determined in the long run.

Consequently, economies with identical economic fundamentals, and different initial conditions for physical, and human capital will end up with different levels of per capita income. Accordingly, the model predict converge in growth rates but not in per capita income levels.

### 3.1 Transitional Dynamics

If the economy starts with initial conditions such that the ratio $\frac{k(0)}{h(0)}$ is different than that of a stationary point, say $\frac{k(0)}{h(0)} > \left(\frac{k}{h}\right)^*$, how is the investment rate in human capital compared to that along a balanced growth path? How is the evolution of $k(t)$ and $h(t)$ to reach the balanced growth ratio, $\left(\frac{k}{h}\right)^*$? How fast the economy approaches the balanced growth path? In the next section, we provide answers to these questions. We show that a neat characterization of the transitional dynamics can be given in this model.

The speed of convergence of equilibrium paths toward the balanced growth path provides important information in order to evaluate the consequences of public policies. Policy analysis based on long-run comparisons may misestimate the welfare effects of policies by ignoring its short-run effects. As we shall see in the next section, the introduction of a flat-rate tax on capital income increases consumption in the short run, which relieves part of the burden caused on the long run. Disregarding the transitional period will hence translate in an overestimation of the welfare cost of capital income taxation.

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**Biographical Sketch**

**Professor Salvador Ortigueira** teaches economics at Cornell University. He studied economics at Universidad de Santiago de Compostela (Spain), and obtained MA and Ph.D. degrees in economics from Universidad Carlos III de Madrid. His main research areas are growth theory, public finance, and unemployment theory.