

## MODELS OF ECONOMIC GROWTH

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### Summary

This chapter presents a survey of models of economic growth starting with the Harrod-Domar growth model, which is based on Keynesian ideas of incomplete markets, and continues with the neoclassical model of exogenous growth. In the latter, the supply side plays the decisive role and the article characterizes the properties of this basic growth model. A shortcoming of this model is that it cannot endogenously explain sustained per-capita growth, which is an empirically observed fact in market economies, but has to resort to exogenously given technical change. The reason for this problem lies in the fact that the production function is characterized by a declining marginal product of physical capital which reduces the incentive to invest as capital rises. As a consequence, the economy converges to a steady state in the long-run where investment is just sufficiently high to keep the per-capita capital stock constant. The endogenous growth theory could overcome this shortcoming by postulating that there exist endogenous factors that have positive effects on the marginal product of capital. This contribution depicts fundamental endogenous growth models starting with the model where investment is associated with positive externalities on the macroeconomic level. These externalities raise the marginal product of capital and prevent that the incentive to invest vanishes as capital grows, leading to sustained growth in the long-run. Another class of endogenous growth models assumes that research and development is undertaken by profit maximizing firms thus raising the stock of knowledge that

generates sustained per-capita growth. The last two class of models presented are the one with human capital formation as the source of ongoing growth and the one where the government continually invests in public infrastructure which has a stimulating effect on the private investment share. The article also discusses the dynamic behavior of the models presented and points out empirical evidence for each class of models.

## 1. Introduction

Over the 18<sup>th</sup>, 19<sup>th</sup>, and 20<sup>th</sup> centuries aggregate production has been more or less steadily increasing in most countries of the world. This holds both as concerns overall output as well as concerns production per capita. So, the per-capita gross domestic product (GDP) in the world quadrupled from 1900 to the early 1990's, corresponding to an average growth rate of about 1.5 percent per year. In Western European countries, GDP growth was still larger with an average annual growth rate of roughly 1.9 percent which implies that per-capita GDP in the early 1990's was 5.6 times larger than in 1900. Whereas the rise in overall output does not seem to be too surprising as the population of a country increases, this does not necessarily hold for per-capita output. Although both aspects are of importance and have been studied by economists, it is in particular the latter question which has especially raised the interest of economists.

Already the classical economists of the 18th and 19th century have addressed the question of which factors generate economic growth. Adam Smith, who is commonly considered as the founder of modern economics, regarded savings in an economy, which are used for capital formation, as an important factor for growth since it leads to higher labor productivity and, thus, to more output per worker. David Ricardo, the famous follower of Adam Smith, also underlined the importance of capital accumulation but, in addition, stressed the important role played by technical progress. Although both theories already incorporated important elements which are still relevant for the growth process in modern economies, they also contain elements which turned out to be wrong. This holds for example for the prediction that the limited availability of land brings economic growth to a standstill, a fact which turned out not to be correct.

Instead, aggregate output per-capita in market economies still continues to grow and there does not seem to be a tendency for declining growth rates. Since the gross domestic product in an economy is an important aspect determining welfare and well-being of people in a country, the understanding of the growth process is an important topic in economics. The importance of understanding economic growth becomes the more obvious since it allows governments to exert influence on the process of economic growth once the forces are known which lead to increases in GDP.

In this contribution we intend to give a survey of models of economic growth which try to explain the growth process in market economies. We start in the next section with a description of stylized facts of the growth process. In Section 3, we present basic exogenous growth models where we depict both a Keynesian growth model as well as the neoclassical model. Modern models explaining economic growth endogenously are presented in Section 4 and Section 5, finally, concludes.

## 2. Stylized Facts

In modern economics, stylized empirical facts play an important role. This is because more and more theoretical models are used to explain empirical observations and to derive policy implications. If theoretical models are not capable of replicating at least the most important facts their relevance is only limited. This appears to be a promising route, although one has to admit that it is still ambiguous and debatable what stylized facts in macroeconomics are. Nevertheless, it seems that empirical regularities about economic growth, which are pretty robust, can be identified which had been done already in the 1960's. The following observations represent stylized facts in growth theory.

- The ongoing growth in aggregate production and in the productivity of labor, with no tendency for a falling rate of growth.
- A continued increase in the amount of capital per worker.
- Steady capital-output ratios over long time periods.
- A steady rate of return to capital which exceeds the long-term rate of interest.
- A high correlation between the share of profits in income and the share of investment in output and a steady share of wages and physical capital in national income.
- There are considerable differences in the rate of growth of labor productivity and of total output in different economies.

Since these observations date back to the 1960's, the question arises whether these facts can indeed be confirmed. So, modern empirical studies have tried to answer this question for different countries. The conclusion they reach is that all stylized facts can be more or less confirmed for developed countries with the exception of the fourth. It is argued that the assumption of a stable real rate of return should be replaced by the hypothesis of a slightly declining rate of return as an economy evolves over time. The justification for this is to be seen in observations that show that the real rates of return in some fast growing countries, like South Korea, Singapore or Taiwan in the second half of the 20th century just to mention a few, are much higher than those in advanced economies, but the rates have declined over time.

In addition, there are other features of modern economies which are considered as characteristic for the growth process. So, market economies are often subject to a fast rate of structural transformation, implying first the shift from the agricultural sector to the industrialized one and, later on, to the service and information technology sector. Further, the role of technological change in the growth process has become more and more important as countries grow. Moreover, the increased significance of governments in the process of economic growth is also often considered an important aspect. This results from the need for laws to regulate economic transactions and also from the growing significance of public infrastructure in the growth process. Additional characteristics are the reduced dependence on natural resources, the rising importance of foreign trade and the increased role for formal education in schools and universities.

Some of the facts we have just mentioned are rather detailed so that a general growth theory or general models of economic growth cannot necessarily reflect all of those characteristics. However, this does not hold for facts (1) to (3) which are quite general and which should be reflected by theoretical models.

Another aspect which should be pointed out is that economists often maintain a theoretical dichotomy between growth and business cycles. This means that growth theories intend to explain the medium- and long-run trend in output and in production possibilities rather than short run fluctuations in production. The latter is the object of business cycle theory and will not be dealt with in this survey.

### 3. Exogenous Growth Models

#### 3.1. The Harrod-Domar Growth Model

The Harrod-Domar growth theory is based on the work by these two authors. They developed their models independently, but the assumptions and results are, nevertheless, basically the same. They built their theory in the late 1930's and mid 1940's, when the memory of industrialized countries being plunged into deep recessions, with a high unemployment rate and a sharp decline of gross domestic product due to the recession in 1929 and 1930, was still present. Harrod and Domar based their theorizing on the famous work by Keynes who offered an explanation of why markets may fail to bring about full employment.

The early classical writers, mentioned in the Introduction, fully believed in Say's law, stating that supply creates its own demand. This belief was based on the assumption of the efficient working of markets, especially factor markets, and on the speedy adjustment of prices to their equilibrium levels at which demand equals supply. Keynes denied the frictionless functioning of this process and asserted that unemployment of factors is even more probable in an economy than full employment. But his emphasis was on short run implications of his theory underlining the income effect resulting from additional investment, for example. The capacity effect, resulting from increases in the capital stock, however, was neglected by Keynes. It is this latter effect that Harrod and Domar integrated in their work, thus forming a Keynesian theory of economic growth.

The Harrod-Domar model considers a closed economy in which one homogenous good  $Y$  is produced. This good may be either used as an investment good,  $I$ , or as a consumption good,  $C$ . The use of it depends on the economic agent. Households consume and save whereas firms produce and invest. All variables are real and the money market is absent.

The GDP which equals national income at time  $t$ , then, is given by  $Y(t) = C(t) + I(t)$ . Consumption and savings are supposed to be a linear homogenous function of national income, with  $c_m$  the marginal propensity to consume and  $s_m = 1 - c_m$  the marginal propensity to save:  $C(t) = c_m Y(t)$ ,  $0 < c_m < 1$  and  $S(t) = s_m Y(t)$ . The constancy of  $c_m$  and  $s_m$  implies that marginal values equal average values. In addition, an equilibrium condition is imposed assuring that investment equals savings in every period. Another condition asserts that firms intend to realize a certain capital-output ratio  $v^d = K^d(t)/Y(t)$ , where the superscript d denotes desired values. This capital-output ratio  $v^d$  reflects the notion that capital is fully employed if the desired ratio is realized and again brings about the equivalence of marginal and average variables.

If  $v^d$  is constant, capital must grow at the same rate as GDP. This is ensured by investments of firms which take the expected change in national income,  $\dot{Y}^e(t)$ , as a reference, giving  $I(t) = \dot{K}(t) = v^d \dot{Y}^e(t)$ , where the dot over a variable gives the derivative with respect to time. Integration yields  $K(t) = v^d Y^e(t)$  or  $K^d(t) = v^d Y(t)$ , expressing the fact that only the correct anticipation of GDP guarantees the correspondence of realized with desired quantities.

To derive the growth rate for this economy, we note that  $\dot{Y}(t) = \dot{K}(t)/v = s_m Y(t)/v$  holds because  $I(t) = s_m Y(t)$ , which gives  $\dot{Y}(t)/Y(t) = s_m/v$ . The growth rate of the capital stock is obtained from  $\dot{K}(t) = s_m Y(t)$  and  $K(t) = v_m Y(t)$  as  $\dot{K}(t)/K(t) = s_m/v$ . Because  $I(t) = s_m Y(t)$  and  $C(t) = c_m Y(t)$  it follows that  $\dot{I}(t)/I(t) = \dot{C}(t)/C(t) = \dot{Y}(t)/Y(t) = s_m/v$ . These considerations show that there exists a growth path on which GDP, consumption, the capital stock and investment grow at the same rate which is called the warranted rate of growth.

Given the Keynesian character of this model it becomes immediately clear that all variables have to grow at the same rate. If, for example, investment is constant for all years, the level of aggregate demand will also remain constant according to Keynesian multiplier theory. But even a constant level of investment will steadily increase the productive capacity of the economy. This demonstrates that there must be growth in investment in order to prevent that the growth of demand does not fall short of the growth of the productive capacity.

The above reasoning has shown that there exists a warranted rate of growth for a Keynesian economy. But this growth path can only be realized if firms anticipate the growth rate  $s_m/v$  and, thus, choose the correct level of investment. Besides the question of the existence of such a path, it is worth to investigate whether the economy reaches this path if it does not start on it. Let us assume that an economy does not start on the warranted growth path. Then the capital stock as a percentage of investment will decline, or, equivalently, the level of investment per unit of the capital stock will rise, if the actual capital-output ratio is below the desired one and vice versa if it is above the desired ratio. Omitting the time argument  $t$ , this leads to the following differential equation:

$$\left( \frac{d}{dt} \left( \frac{K}{I} \right) \right) / (K/I) = b(v - v^d), \quad b > 0 \quad (1)$$

Using  $I(t) = s_m Y(t)$ , it can be transformed into  $\dot{v} = b v (v - v^d)$ . The economically reasonable steady state for this equation is given by  $v = v^d = K^d/Y$ , which yields the warranted rate of growth. But if firms intend to invest in a way such that  $v^d$  is smaller than  $v = K/Y = s_m K/I$  is larger, implying that the actual growth rate,  $s_m/v$ , is lower than the warranted,  $s_m/v^d$ , investment is further reduced leading to an increase in the ratio  $s_m K/I$  which makes the actual rate of growth diverge still further from the

warranted rate of growth. Of course, the opposite reasoning applies to a level of  $v^d$  which is larger than  $v$ . In this case we observe a perpetual increase in investment and thus in the actual rate of growth.

This demonstrates that the warranted growth rate in the Harrod-Domar model can only be achieved if the economy starts on this path. In any other case it will diverge even further from this path. Therefore, economists speak of a growth process on the knife edge. So, the Harrod-Domar model shows that market economies have an equilibrium growth path, which, however, is unstable. The government in such a system has to try to influence the relevant parameters in a way such that the warranted growth path is guaranteed. But in reality, market economies have had long periods of ongoing growth, even without government intervention. This instability problem inherent in the Harrod-Domar model was the main motivation for developing the neoclassical growth theory which was achieved in the 1950's.

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### Biographical Sketch

**Alfred Greiner** was born in Traunstein, Germany, in December 1963. He studied economics at the University of Augsburg in Germany from 1984 until 1989. Alfred Greiner received his Diploma in Economics in 1989 when he graduated from university. After this, he was employed at that University as a research associate in the Department of Economics where he received the degree Dr. rer. pol. in 1993. From 1994 until 1996 he had a scholarship for habilitation from the German Science Foundation (DFG) and in 1996 Alfred Greiner habilitated at the Department of Economics at the University of Augsburg (Dr. rer. pol. habil.). From 1996 to 1999 Alfred Greiner was assistant professor there and he became professor of Economics at the Department of Business Administration and Economics at Bielefeld University in 2000.

He spent several months at the Graduate Faculty of the New School University in New York as a visiting research fellow and he has published numerous articles in academic journals. He is the author of *Fiscal Policy and Economic Growth* (Aldershot, England: Ashgate Publishing Company, 1996), which was translated into Chinese in 2000, and he is coauthor of the book *The Forces of Economic Growth: A Time Series Perspective* (Princeton, NJ, USA: Princeton University Press, 2005). In 2006 he was a consultant to the World Bank in questions of fiscal policy and economic growth. His research interests are in dynamic macroeconomics with special emphasis on topics in economic growth and in the analysis of fiscal policy as concerns growth and welfare of economies. Alfred Greiner's scientific work is both theoretically as well as empirically orientated.

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