9 Economic Growth: Why Are There Rich and Poor Countries?

Koki Oikawa

Abstract

Sustainable economic growth is one of the main goals of SDGs. To achieve this goal, we need to know what drives the long-run dynamics of the wealth of nations. In this chapter, we first learn how to measure the level of a country's wealth and its growth from data, as well as some widely observed facts such as steady growth in some developed countries, the huge international difference in economic growth, and so forth. Next, we develop theoretical models to explain those observations. We present a basic theory of growth with capital accumulation as the driving force and check the consistency with the observed data. Further, we consider firms' investments into research and development (R&D) and see how innovations drive economic growth. It also tells us the effects of growth policies. Lastly, we discuss other factors that create international difference in economic growth such as education, institution, and misallocation of resources. This chapter contributes to Goal 8 (economic growth) and 9 (innovation) in SDGs.

K. Oikawa (✉)
Waseda University, Tokyo, Japan
e-mail: oikawa.koki@gmail.com

Keywords

Economic growth · Catch-up · Productivity · Technological progress

9.1 Introduction

People living in the United States earn about 100 times the income of people in the poorest countries, after adjusting for price levels. Why are some countries so rich? Why do some countries grow faster than others? Can a poor country become rich in the future? If they can, how? These are questions in macroeconomics since our predecessors began to study the mechanism of economic growth and development. Honestly speaking, we do not have quick answers to those questions yet. However, accumulated knowledge in this academic field gives us a good perspective on the appropriate approach to tackle them. Learning the fundamental framework to analyze economic growth, which is developed in this chapter, definitely helps us achieve the sustainable development.

In this introduction, we review several important facts about economic growth using worldwide time-series data. Let us start by introducing the data we focus on. The wealth of a nation is usually measured by its gross domestic products (GDP, hereafter), which captures how much final goods and services are produced in a year. Because we are more interested in people's liv-

S. Urata et al. (eds.), *Sustainable Development Disciplines for Society*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-981-19-5145-9_9

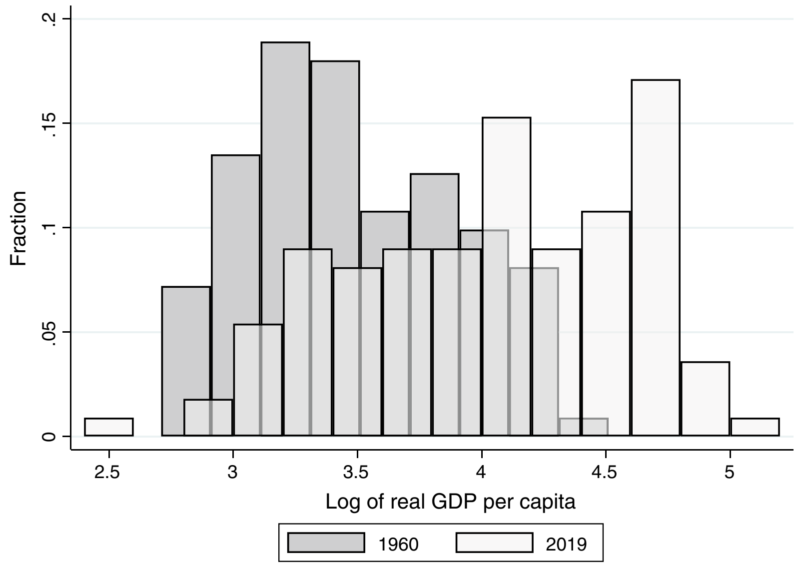


Fig. 9.1 Histograms of log of real GDP per capita in 1960 and 2019. *Source* PWT10.0

ing standards rather than the aggregate size, we divide the total GDP by the population to obtain per-capita GDP. Additionally, we remove the effect of price changes from GDP to avoid misinterpreting an increase in GDP owing to inflation as real economic growth. Finally, we adjust for differences in the price level between international economies to compare multiple countries that use different currencies.

Figure 9.1 shows the histograms of real GDP per capita across countries in 1960 and 2019.[1] We need to clarify how to read this graph. Because the numbers for real GDP per capita are too diverse, for example, from 500 to 23,000 in 1960 (in US dollars based on 2017), to depict in an easy-to-read graph, one can make such a graph readable and concise by taking the logarithm of the numbers. Here, we use a logarithm with the base of 10, or $\log_{10} y_t$, where y_t is real GDP per capita in year t. Note that the logarithm converts 10^x to x, or, in equation, $\log_{10} 10^x = x$. This x is taken as the horizontal axis in Fig. 9.1. So, if a country has $x = 4$ on the axis, its real GDP per capita is $y = 10^4 = 10{,}000$. If country A has 4 and country B has 3 on the horizontal axis, country A is 10 times larger than country B.

The takeaways from this figure are threefold. First, both histograms in 1960 and 2019 have wide ranges on the horizontal axis, implying that there exists a sizable dispersion in the level of per-capita real GDP. Second, the observed dispersion is persistent. Third, the histogram shifts rightward from 1960 to 2019, implying that the real GDP per capita is growing over time on average.

Next, Fig. 9.2 shows a histogram of the average annual growth rate of real GDP per capita from 1960 to 2019. The growth rates are mainly positive, but, again, there is a significant dispersion. Can you imagine how much difference there is between a country with a growth rate of 5% and another with 1% over 60 years? Even though the initial levels are common, the faster-growing country becomes more than 10 times richer than the other after 60 years, as shown in the calculation of $(1 + 0.05)^{60}/(1 + 0.01)^{60} \approx 10.28$.

Figure 9.3 illustrates the relationship between the initial level of real GDP per capita (in 1960) and the average growth rates afterward, using the same data in Figs. 9.1 and 9.2. This figure tells us about international convergence more clearly. If poor countries catch up with rich countries, a

[1] The data source is Penn World Table (PWT), version 10.0. You can download the worldwide data related to economic growth from https://www.rug.nl/ggdc/productivity/pwt/. The histograms consist of 111 countries and regions that have GDP data in both years.

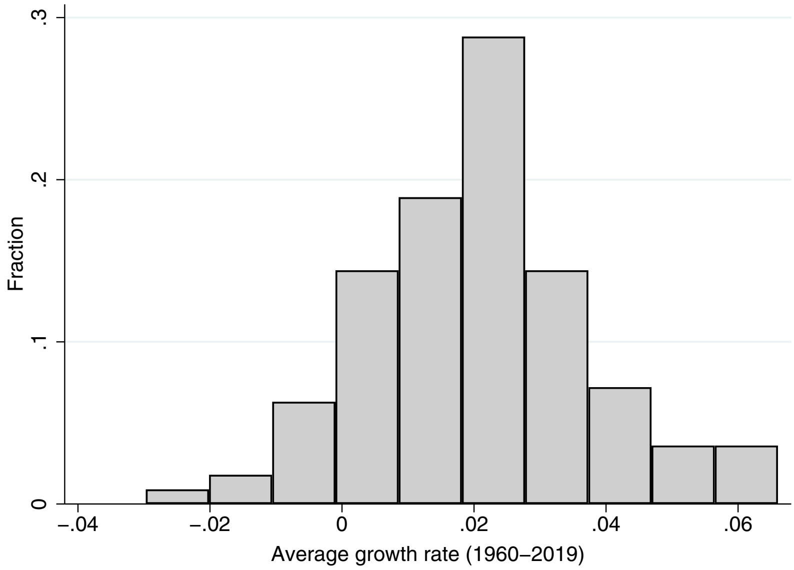


Fig. 9.2 Histogram of growth rate. *Source* PWT10.0

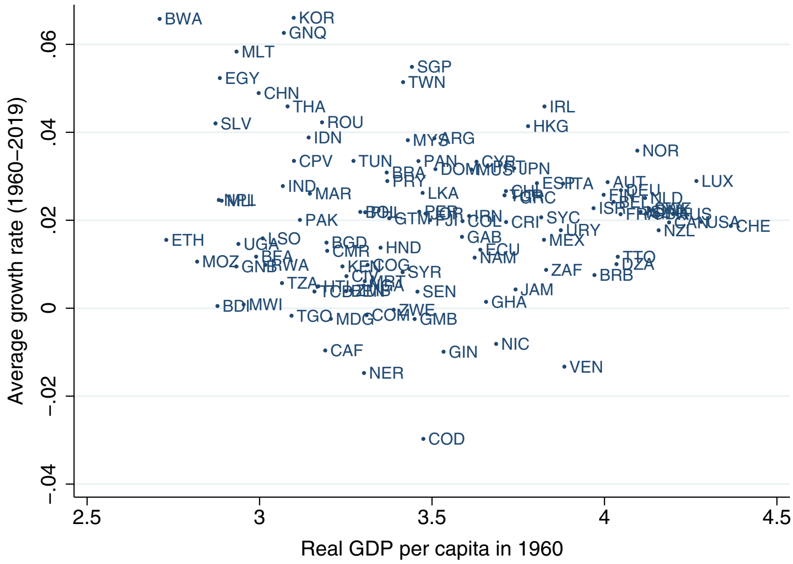


Fig. 9.3 Catching up? *Source* PWT10.0

low initial GDP level (horizontal axis) should be associated with a high growth rate (vertical axis). Indeed, some countries around the top-left corner in the figure, such as Botswana (BWA) and South Korea (KOR), have been catching up during these past several decades. However, it does not hold in general. The countries in the bottom-left area in the figure have low initial levels and low or negative growth rates. Some of those countries are lagging, rather than catching up with the richer countries.

In the next section, we argue about the mechanism behind these observations. To see how the long-run growth is determined, we first introduce a basic economic growth model in Sect. 9.2. The basic model explains some aspects of economic growth but, at the same time, casts a light on what we are ignorant of to explain economic growth.

Hence, in Sect. 9.3 and subsequent sections, we dig deeper into the growth mechanism.

Basics in Macroeconomics

Here, we quickly review the definitions and ideas in macroeconomics used in the following discussions. If you are familiar with introductory macroeconomics, you can jump to the next section.

First, GDP is constructed to represent output, expenditure, and income using a single statistic. The idea is as follows. Produced final goods (output) are purchased by someone (expenditure). Moreover, cash flows to firms through sales are distributed as income to households in various forms such as wages, interests, and dividends (income). The amount of cash flows calculated from the three aspects is identical.

Second, four sectors construct macroeconomy: households, firms, governments, and foreign countries. Each of them purchases goods and services from the market. The expenditure of households in year t is called consumption C_t, expenditure of firms is investment I_t, expenditure of the government is G_t, and the net expenditure of foreign countries is net export NX_t (export minus import). From the expenditure view of GDP, we have the following identity in the national accounts:

$$Y_t = C_t + I_t + G_t + NX_t,$$

where Y_t stands for GDP. In the following arguments, however, we consider the domestic private sectors in the economy, namely households and firms, to focus on the essence of the growth mechanism. Hence, the above identity becomes $Y_t = C_t + I_t$, and then the saving equals investment, i.e., $S_t = Y_t - C_t = I_t$, because Y_t is also the aggregate income by definition, as mentioned in the previous paragraph.

The mechanism behind the equality of saving and investment is the supply–demand equilibrium in the funds market, where saving is the supply of funds and investment is the demand for them. Because high interest rates are a burden for fund-rasing firms, they do not execute investment projects whose expected returns are not large enough, relative to the interest payments. In other words, investment decreases with the interest rate. When the supply of funds is greater than its demand, the interest rate declines so that firms become able to afford to invest more. With the interest rate as the adjusting device, the demand–supply equilibrium in the funds market guarantees the equality of saving and investment.

Third, we consider a production function that generates real GDP, such as $Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$, where K_t is capital equipments, L_t is labor force, and A_t is productivity. In particular, A_t is called *total factor productivity* (TFP). In the following arguments, we suppose that this production function determines the level of GDP, implying that GDP depends solely on capital and labor endowments and the technology in year t. Note that we care about only the supply-side conditions and do not consider the demand-side conditions, whereas a shrink in demands is considered significant for economic fluctuations. The reason why we ignore the demand-side conditions is that we deal with the long-run behaviors of economies, as we observe economic growth over several decades in the above figures. In the standard arguments in macroeconomics, the long-run trend of an economy is considered to be determined by the supply side conditions, and short-run business cycles, where demand side conditions matter, are considered diversions from the long-run trend.

9.2 Basic Theory of Economic Growth

9.2.1 Solow Model

Sustained growth can be explained by a simple model established by Robert Solow. Figure 9.4 shows the time series of the log of the real GDP per capita in the United States as a typical example of frontier economies, with the fitted linear line showing the long-run trend. The linear trend shows a good fit to the actual GDP data, which implies that the growth rate is constant in the long run. Moreover, we can extend this trend line dating

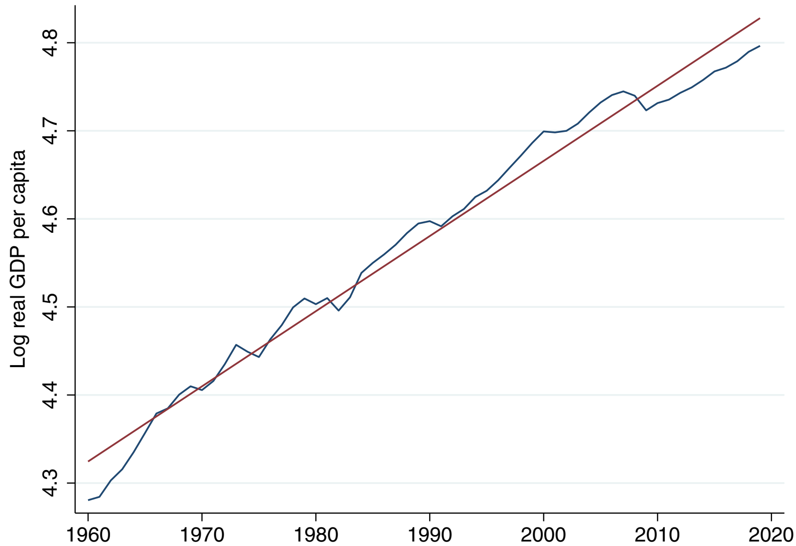


Fig. 9.4 Steady growth in the United States. *Source* PWT10.0

back to the mid-nineteenth century. The average growth rate is slightly less than 2% for over 150 years in the United States. There must be a rationale to support such a strikingly long-lasting steady growth. This is our starting point in the theoretical approach.

The Solow model supposes capital accumulation as the main factor to drive the dynamics of economies. To relate capital formation and economic growth, Fig. 9.5 shows the scatter plot of the average growth rate and the average investment shares in GDP from 1960–2019, with the fitted line. There clearly exists a positive correlation between the average investment shares and the average growth rates, implying that countries with large investments tend to grow faster.

To focus on the essential mechanism, we make the model as parsimonious as possible. Let there be only the domestic private sectors in the economy: households and firms. The real GDP in year t, Y_t satisfies

$$Y_t = C_t + I_t,$$

where C_t and I_t are the real consumption and investment, respectively. We assume a constant saving rate of households, s, so that $C_t = (1 - s)Y_t$ and

$$I_t = Y_t - C_t = sY_t, \qquad 0 < s < 1. \tag{9.1}$$

Investment, I_t, is the amount of newly equipped machines in year t, which constructs the real capital in the next year, K_{t+1}, which is the total amount of machines at period $t + 1$. Assuming that machines are broken in each period at the rate of δ, we represent capital accumulation as

$$K_{t+1} = (1 - \delta)K_t + I_t \qquad 0 < \delta < 1. \tag{9.2}$$

Outputs are produced with capital and labor as inputs according to the production function,

$$Y_t = K_t^{\alpha} L_t^{1-\alpha}, \qquad 0 < \alpha < 1, \tag{9.3}$$

where α represents capital share in the sense that α of total income is distributed to capital owners (and $1 - \alpha$ goes to workers).[2] For simplicity, we assume no population growth. L_t is constant over time, and, more specifically, we set $L_t = 1$. Then, Y_t is equivalent with real GDP per capita. The production function (9.3) becomes

$$Y_t = K_t^{\alpha}. \tag{9.4}$$

[2] From the viewpoint of income distribution, real GDP satisfies $Y_t = r_t K_t + w_t L_t$, where r_t and w_t are the real interest rate and the real wage, respectively. The capital share is measured by $\frac{r_t K_t}{Y_t}$, and the labor share is measured by $\frac{w_t L_t}{Y_t}$.

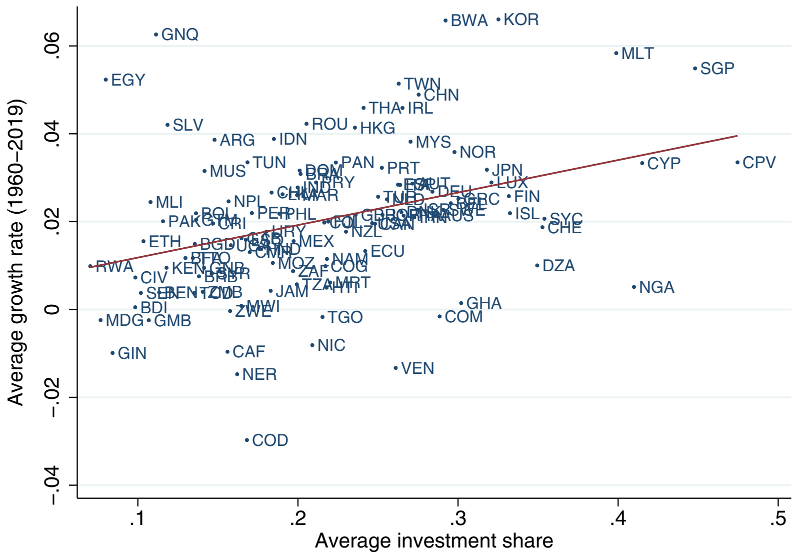


Fig. 9.5 Average investment share and average growth rate (1960–2019). *Source* PWT10.0

Substitute equations (9.1) and (9.4) into (9.2), we have

$$K_{t+1} - K_t = sY_t - \delta K_t = \underbrace{sK_t^{\alpha}}_{\text{investment}} - \underbrace{\delta K_t}_{\text{depreciation}}, \tag{9.5}$$

which determines the law of motion of capital. We find that there are two opposing forces at work. If investment is greater than depreciation, capital increases such that $K_{t+1} > K_t$. Contrarily, if investment is smaller than depreciation, $K_{t+1} < K_t$. Figure 9.6 illustrates how these two forces balance. As drawn in the figure, when capital is K_t^A, investment is greater than depreciation. Then, capital increases in the next period. However, if capital is at K_t^B, depreciation excesses investment, and the capital stock will decrease. Figure 9.6 also depicts K^* at which investment equals depreciation so that the capital stock remains constant. Such K^* is called the *steady state*. If the economy is at the steady state, nothing changes over time unless a shock perturbs the state of the economy. Moreover, Fig. 9.6 tells us that, starting from any positive level of capital stock, the economy converges to the steady state K^*. If the capital is less than K^*, like K_t^A, the capital increases and approaches K^*. If it is higher than K^* like K_t^B, it decreases and gets closer to K^*. Hence, the economy is in the steady state in the long run. In the current setting, the steady-state level of capital is

$$K^* = \left(\frac{s}{\delta}\right)^{\frac{1}{1-\alpha}}. \tag{9.6}$$

Note that the output Y_t is determined by the level of capital K_t. Thus, at the steady state of capital, the output is also in the steady state, meaning no changes over time. The output attains $Y^* = K^{*\alpha}$, and the per-capita real growth rate is zero in the long run.

Exogenous Technological Progress The above simple model can easily incorporate exogenously growing factors. If we introduce population growth such that $L_{t+1} = (1+n)L_t$, the per-capita output remains constant while the aggregate real output grows at the rate of n in the steady state.

Similarly, we can introduce exogenous technological progress in the form of

$$Y_t = K_t^{\alpha}\left(A_t L_t\right)^{1-\alpha}, \tag{9.7}$$

where A_t represents the effectiveness of one unit of labor. We assume that A_t grows at the rate of g, or $A_{t+1} = (1+g)A_t$. Then, in the steady state,

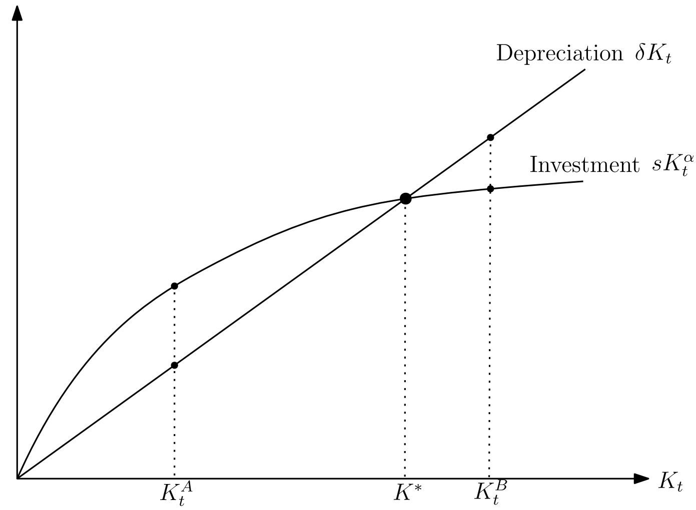


Fig. 9.6 Capital dynamics and the steady state in the Solow model

the per-capita output grows at the rate of g and the aggregate output grows at the rate of $n + g$.

Now, we got the theoretical result of steady growth observed in Fig. 9.4. The growth rate is stable because the economy is in a steady state. Positive growth in the per-capita term occurs because of technological progress. If the technological progress rate is not that turbulent, the economy grows at a constant rate on average.

9.2.2 Conditional Convergence Across Countries

Although the Solow model presents an explanation of economic growth in some frontier economies such as the United States, is it consistent with the international difference in the GDP levels and growth rates, observed in Figs. 9.1, 9.2 and 9.3? Here, we consider whether a poor country will catch up with a rich one in the Solow model.

Let g_t^K be the growth rate of capital from year t to $t + 1$. In an equation, it is given by

$$g_t^K = \frac{K_{t+1} - K_t}{K_t}.$$

The relationship between the level and growth in the Solow model is depicted in Fig. 9.7. It is simply from the law of motion of capital, equation (9.5), such that

$$g_t^K = \frac{K_{t+1} - K_t}{K_t} = sK_t^{\alpha-1} - \delta,$$

which is decreasing in K_t because $\alpha - 1 < 0$. Therefore, a country with lower capital stock, K_a in the figure, has a higher growth rate than countries with abundant capital stock.

So far, it seems like poor countries will eventually catch up with the frontier economies that are considered to be around the steady state, K^*. However, it is the case only when every country has an identical steady state.

As shown in Eq. (9.6), the steady-state level of capital per capita is determined by parameters s, δ, and α. If we incorporate population growth and technological progress, it also depends on the population growth rate, n, and the technological progress rate, g, too. Since those parameters vary from country to country in reality, the steady state also varies.

For example, suppose that countries A and B are different in their saving rates, say $s_A > s_B$, while the other parameters and the initial capital stock, K_0, are the same. From Eq. (9.6), the steady-state levels of capital per capita are $K_A^* > K_B^*$. Even though the initial capital is the same across the two countries, the distance from the initial position to the steady-state level is greater in country A, or $K_A^*/K_0 > K_B^*/K_0$. Now apply Fig. 9.7 to each country separately. In the figure for country A, the initial capital is small relative

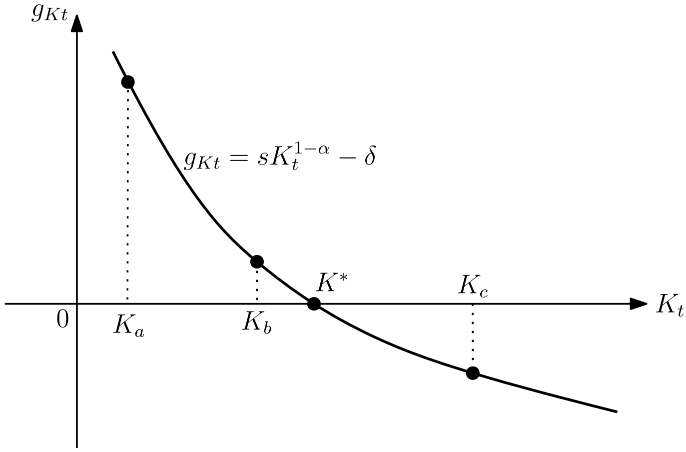


Fig. 9.7 Level and growth of capital in the Solow model

to the steady state as if K_0 is around K_a. On the other hand, in the figure for country B, the initial capital is close to the steady state as if K_0 is around K_b. Then, country A has a higher growth rate than country B even though the initial capital levels are the same.

Therefore, the distance to the steady state is significant in the relationship between GDP levels and growth rates. Low growth countries have low levels of steady state. If this is the case, such a poor country never catches up with a rich country unless there occurs a shock or policy intervention on some parameters such as the saving rate, technological progress rate, and so forth.

Poverty Trap

While we divert a bit from the main context in this chapter, here, we present another way to explain the stagnation of a poor country by extending the Solow model. Suppose that there is a subsistence level of consumption $\bar{C}$. When the income level is less than or equal to $\bar{C}$, they cannot afford to save and just consume all the income. They have positive savings (and investment) only when $Y_t > \bar{C}$. This situation is described by the investment function,

$$I_t = \begin{cases} 0 & \text{if } Y_t \leq \bar{C}, \\ s\left(Y_t - \bar{C}\right) & \text{otherwise.} \end{cases}$$

The other settings are the same as in the baseline model.

The diagram for this modified Solow model is illustrated in Fig. 9.8. The difference from Fig. 9.6 is that the intercept of the investment curve lies at a positive value on the horizontal axis, which creates two intersections with the depreciation curve. The upper intersection at K^* is similar to the steady state in the basic model. The lower intersection at $\hat{K}$ indicates the divide between the shrinking economy and the growing economy. If K_t is greater than $\hat{K}$, the investment is more than depreciation, and the economy grows. If K_t is less than $\hat{K}$, investment is not enough to compensate the amount of depreciation, and capital stock decreases over time.

Even though the upper steady state K^* is potentially possible, a country may be trapped on the left side of the divide at $\hat{K}$ if it initially lacks a sufficient amount of capital stock. This case is called a *poverty trap*. In order for a developing country to escape from the poverty trap, it needs a big push via official development assistance (ODA) or foreign direct investments with which the capital level is pushed up beyond the dividing border, $\hat{K}$.[3]

[3] Although the poverty trap discussed here gives us an insight about economic development, it is difficult to estimate how big is the required push to go across $\hat{K}$. Evidence-based policy evaluation is hard without tracking how foreign aids are distributed into the economy. In response

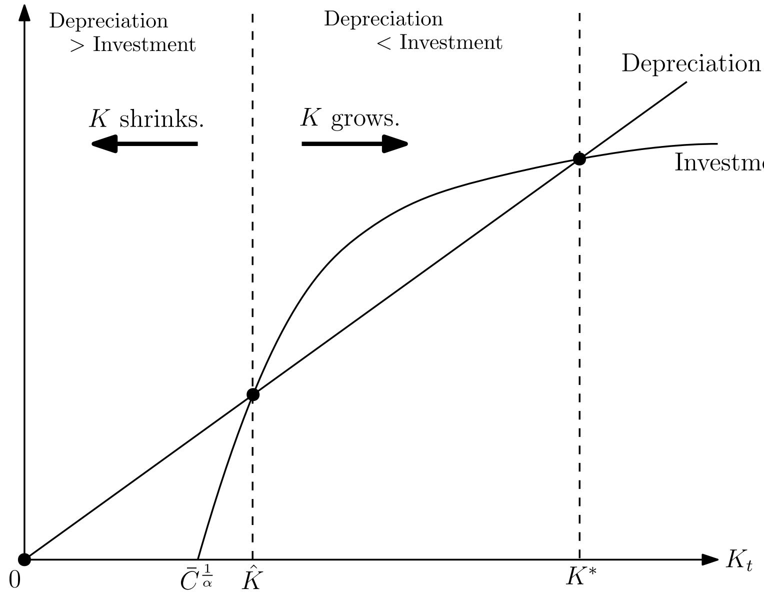


Fig. 9.8 Poverty trap

9.2.3 Growth Accounting

The Solow model focuses on capital accumulation as the growth engine, and population and productivity growth are exogenous factors. However, how important is those exogenous growing factors in the data? In this subsection, we run *growth accounting* to investigate the contribution to the growth of each factor that determines GDP.

We consider a slightly different production function such that

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{9.8}$$

where A_t is TFP.[4] We calculate the relationship among growth rates of variables in this production function. Consider the change rate from t to $t+1$ such that

$$\frac{Y_{t+1}}{Y_t} = \frac{A_{t+1}}{A_t}\left(\frac{K_{t+1}}{K_t}\right)^{\alpha}\left(\frac{L_{t+1}}{L_t}\right)^{1-\alpha}.$$

Define the growth rates $g_t^x = x_{t+1}/x_t - 1$, where x can be Y, A, K, and L. Then,

$$1 + g_t^Y = \left(1 + g_t^A\right)\left(1 + g_t^K\right)^{\alpha}\left(1 + g_t^L\right)^{1-\alpha}.$$

It is well known that the above equation is approximately equal to the following relationship,[5]

$$g^Y = g^A + \alpha g^K + (1-\alpha) g^L, \tag{9.9}$$

where the aggregate data of GDP and related variables are open to the public in many countries. g^Y is the real GDP growth, g^K is growth in real capital stock, g^L is growth in total working hours, and α is the average capital share. Only g^A can

to those critiques, the recent development studies focus on micro-evidences using randomized controls to obtain evidence-based policy evaluation. I recommend Banerjee and Duflo [3] to interested readers.

[4]Note that this function form is interchangeable with Eq. (9.7), where we can define TFP as $A_t^{1-\alpha}$.

[5]To derive Eq. (9.9), we take the logarithm of both sides such that

$$\log\left(1 + g^Y\right) = \log\left(1 + g^A\right) + \alpha \log\left(1 + g^K\right) + (1-\alpha)\log\left(1 + g^L\right),$$

where the base of the logs is e, i.e., natural logarithm, and we drop time subscript for notational simplicity. Next, we use approximation such that $\log(1+x) \approx x$ if x is sufficiently close to 0, which comes from the first-order Taylor expansion.

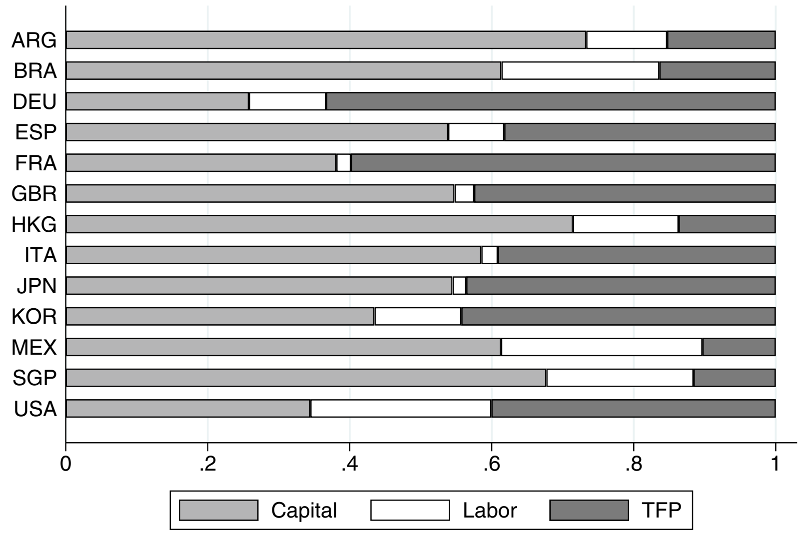


Fig. 9.9 Shares of contribution of capital, labor, and TFP to economic growth. *Source* PWT10.0

not be observed directly, but it is calculated from Eq. (9.9) as $g^A = g^Y - \alpha g^K - (1-\alpha)g^L$.

We are interested in what percentage of economic growth remains unexplained by observable factors such as capital and labor. So, we define the share of contribution of capital accumulation real economic growth as $\alpha g^K / g^Y$ when all growth rates are positive. When some growth rates are negative, we define the contribution as

$$\frac{\alpha|g^K|}{|g^A| + \alpha|g^K| + (1-\alpha)|g^L|},$$

where $|g|$ is the absolute value of g.[6]

Figure 9.9 shows the result of growth accounting for the sample periods of 1960–2019 in 13 countries/regions.[7] The set of the countries/regions is limited mainly due to the lack of data required to conduct the above procedure. The figure confirms that capital accumulation is important, as the Solow model supposes. However, at the same time, it also implies that the contribution from TFP is significant in many countries.[8] The average contribution of TFP in the current sample is about 35%. In some countries, it amounts to 50% or more. This result motivates us to take a closer look at TFP. However, what the Solow model tells us is that per-capita real GDP has steady growth if productivity grows at a given constant rate. It is nothing about what determines the level and evolution of the productivity. We are going to address this question in subsequent sections.

9.3 Endogenous Growth: How Is the Growth Rate Determined?

As discussed above, we need to explain TFP growth to uncover the mechanism of economic growth and to obtain an insight for growth policy. In this section, we introduce a new framework, an *endogenous growth model*, in which the economic growth rate is endogenously determined.

[6]Consider the case in which $g^Y = 0$, $\alpha g^K = 0.05$, and $(1-\alpha)g^L = 0$. In this case, $g^A = -0.05$ and the contribution ratios of capital and TFP are 1/2 for each (and zero for labor). This number is generated by $|0.05|/(|0.05| + |-0.05|)$.

[7]The national account data for Germany (DEU) before the integration at 1991 are estimates based on the growth rates recorded for West Germany (Groningen Growth and Development Centre [5]).

[8]There is a discussion on the undervaluation of the contribution of TFP in the procedure described here. Because TFP includes technological progress, newly introduced machinery embodies higher quality, which increases capital contribution. Thus, part of the contribution of the capital comes from the increase in TFP. Taking this relationship into account, the true contribution of TFP is even higher (and the true contribution of capital is lower) than the shares observed in Fig. 9.9.

Although there are a variety of models of endogenous growth, we mainly focus on productivity growth driven by corporate research & development (R&D) activities, which accumulates ideas, knowledge, and techniques for more efficient production in the society.

9.3.1 Economy of Ideas

Before jumping into the new growth model, it is convenient to discuss an important feature of knowledge or ideas. Let us assume that you were Thomas Edison, a giant inventor. You have come up with a new idea for making a light bulb. This new idea, or innovation, is "yours" in the sense that the patent system prohibits any other person or company from commercializing it without permission. However, the idea itself can be shared with thousands of people who will try to create the next generation of light bulbs based on your idea, including ones that last longer, are safer, and are brighter. An inventor who significantly improves your light bulb will obtain a new patent.

This story highlights three things. First, ideas are *non-rival* goods in the sense that its use by someone else does not prevent others from using the same goods. So, ideas have an aspect of public goods.[9] Second, ideas are inputs for subsequent idea creation. An inventor or researcher learns the existing ideas developed by predecessors and tries to create a new idea relying on them. A little dwarf on the giant's shoulder can see further than the giant.[10] New ideas are born on the giant's shoulder, and these ideas accumulate to make the giant even bigger. Third, as suggested by the above two characteristics, the private and social benefits of innovation are different. The private value is the profit derived from the product designed by the idea, which is only a part of the social value of innovation. The social value also depends on future innovations inspired by the current idea. In the story at the beginning of this subsection, Edison and the subsequent inventors pursue rents from commercializing a new idea, which is the private benefit. If you predict sufficiently large rents, it is worth investing money, time, and effort. However, the innovation is public in some sense because it will be used extensively in subsequent idea creation. Even if the private benefit is negligible, the social benefit might be large. For example, the formula for solving quadratic equations hardly yields profits, but it will help much subsequent research. Because the social benefit of an innovation is greater than the private benefit in many cases, investment for idea creation tends to be smaller than the socially desirable level. This is where we should consider a policy intervention to encourage R&D in the following model.[11]

9.3.2 R&D-Driven Growth

We consider the economy with two sectors in which workers find a job: One is the production sector and the other is the research sector. We assume no skill difference between the sectors for simplicity. Denote L_{Yt} and L_{At} as the production workers and researchers, respectively. Assuming that $L_t = 1$ and define the share of researchers as ρ_t, we have $L_{At} = \rho_t$ and $L_{Yt} = 1 - \rho_t$.

The production sector is the same as in the Solow model with technological progress,

$$Y_t = K_t^{\alpha} \left(A_t L_{Yt}\right)^{1-\alpha},$$

but now A_t does not grow automatically; it grows in response to the researcher's work.

Because productivity A_t reflects scientific and technological knowledge in the society, we suppose that A_t is the stock of ideas and R&D activity increases A_t. As discussed in the previous subsection, the input of idea creation is the stock of ideas, A_t, and researchers, L_{At}. Let $\mu > 0$ be the efficiency in the research sector, and we suppose that A_t evolves according to

[9] The other aspect of public goods is non-exclusiveness. If goods are exclusive, it is possible to prevent someone from using them if the person does not pay the price. Intellectual property rights give exclusivity to an idea.

[10] Such a metaphor, famously described by Isaac Newton as "by standing on the shoulders of Giants," dates back to the Middle Ages in Europe.

[11] Jones and Williams [8] estimate that actual R&D investment is less than half of the optimal R&D investments.

$$A_{t+1} = A_t + \underbrace{\mu A_t L_{At}}_{\text{new ideas}}. \tag{9.10}$$

In other words, one researcher creates μA_t units of ideas.[12] Then, the growth rate of A_t is given by

$$g_t^A = \frac{A_{t+1} - A_t}{A_t} = \mu L_{At} = \mu \rho_t.$$

Now, we focus on a *balanced growth path*, generalization of steady state, where each variable has a constant growth rate over time. Note that the steady state in the Solow model is a balanced growth path because the output per capita has a constant growth rate of zero. On a balanced growth path, g_t^A is fixed at some constant so that ρ_t must be a constant. Let ρ be the number of researchers on a balanced growth path, and we have $g^A = \mu\rho$. Then, applying the last argument in Sect. 9.2.1, we have $g^Y = \mu\rho$.

The argument so far lets us know that what determines the growth rate is the share of researchers or the intensity of R&D activity in the economy. If an economy is more R&D-intensive, it grows faster. However, in what case, is $\rho > 0$ supported? It depends on the balance between the value of a new idea and the cost to create it. When there is a limited labor supply, wages become higher. A very high wage implies that research costs do not meet the reward from the research, which is the future monopoly rents protected by patents. In such a case, there is no incentive to carry out R&D projects, and ρ turns out to be zero on a balanced growth path. Therefore, we need a sufficient amount of potential resources employed in the research sector to have a positive growth rate in the long run. Certainly, the strength of patent protection is another factor to motivate R&D. Without patent protection, innovators cannot monopolize the market for the product they created because imitators enter the market without paying R&D costs or license fees. The reward for innovation is limited under weak patent protection.[13]

The R&D-driven endogenous growth model opens the black box of TFP at least partly. It illustrates the mechanism that long-run economic growth is achieved by R&D activities. Moreover, it implies that the more the R&D, the higher the growth rate. Hence, the policy implication is straightforward: Encouraging investment in R&D will lead to rapid economic growth. As argued in the previous subsection, promoting R&D is desirable from the social viewpoint.

There are several ways to promote R&D, such as R&D subsidy, R&D tax credit, patent reform, easing of financial constraints on firms, and so forth. Some policies could affect the efficiency in the research sector, μ. Because a better collaboration of researchers can create better ideas, a matching mechanism may help increase research efficiency at the aggregate level. We need to exclude discrimination when building research teams. A researcher with appropriate expertise should be employed as a team member regardless of gender, nationality, or skin color, which increases the efficiency of researcher allocations in the aggregate economy.

9.3.3 Growth Without Scale Effect

The model in the previous subsection has one deficit. If we remove the simplifying setting of $L = 1$, the growth rate becomes $\mu\rho L$ instead of $\mu\rho$. Thus, the above model implies that the scale of the economy matters for its economic growth rate. This is called the *scale effect*. But, if there were two identical countries, would merging the two

[12] One may be wondering how we define the unit of ideas. A standard way to keep track of ideas in empirical research is by counting the number of quality-adjusted patents. Quality adjustment is important because many patents are not used to produce any goods while some patents are essential.

[13] There are many discussions about the patent system. Patents provide an incentive to innovate, but it sometimes imposes a cost for the next innovations. When strong protection is given to existing patents, inventors have to present significant novelty and originality to get a new patent successfully. A company adopting a new technology would have a higher risk of litigation from an existing patent holder. Hence, the optimal design of a patent is a controversial issue. See Jaffe and Lerner [7] for more discussion. Some researchers argue that innovations will continue to occur even without a patent system, using the development of open-source software as an example Boldrin [4].

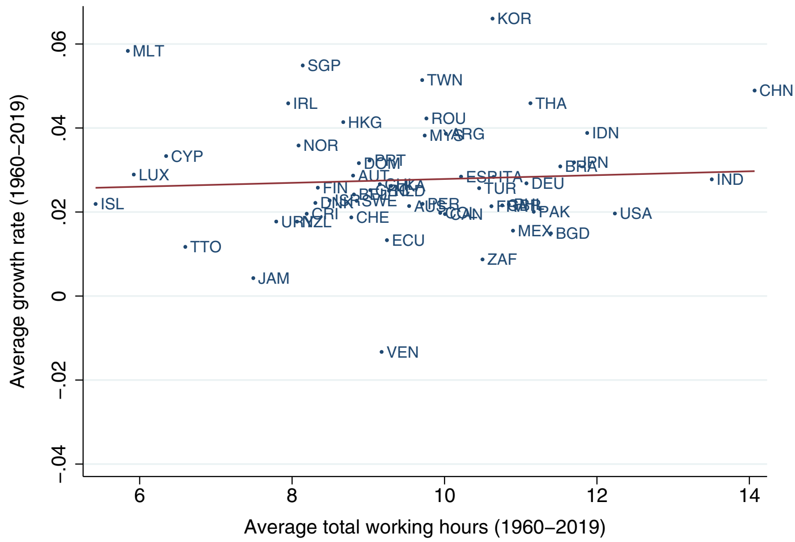


Fig. 9.10 Scale effect? *Source* PWT10.0

produce a country with double the growth rate? Moreover, the above model suggests that the real growth rate increases over time if we allow a positive population growth rate instead of a constant L. Is it plausible?

Figure 9.10 scatters the average growth rates and the average total working hours across countries and regions, and we see no significant correlation between the two variables.[14] Perhaps, the above model overemphasizes non-rivalry and the idea production process, although it captures an important aspect of technological progress. Here, we modify the model to get rid of the scale effect.

The idea production function, equation (9.10), is linear in the stock of ideas. As scientific knowledge evolves, however, it is getting more complicated and catching up with the frontier knowledge requires more effort of learning for researchers than before. It is natural to consider that creating a new idea is getting harder as knowledge accumulates. Then, research productivity is not linearly increasing in the existing knowledge. This situation can be captured by the following slightly modified idea production function such that

$$A_{t+1} - A_t = \mu L_{At} A_t^{\phi}, \qquad \phi < 1.$$

The parameter ϕ stands for an increasing difficulty along with knowledge accumulation.

With this idea production function, the productivity growth on a balanced growth path is

$$g^A = \frac{A_{t+1} - A_t}{A_t} = \mu L_{At} A_t^{\phi-1} = \frac{\mu L_{At}}{A_t^{1-\phi}}, \tag{9.11}$$

where $L_{At}/A_t^{1-\phi}$ must be constant over time. To keep it constant, the numerator and the denominator must have the same growth rate. Since L_{At} stops growing if there is a constant upper bound of L, we allow L_t to grow at rate of n. Then, the balanced growth is achieved when all the growth rates of L_t, L_{At}, and L_{Yt} are n. Hence, $A_t^{1-\phi}$ also grows at n to keep the fraction in the right-hand side of Eq. (9.11) constant, that is,

$$\left(\frac{A_{t+1}}{A_t}\right)^{1-\phi} = 1 + n$$
$$\Rightarrow \quad \left(1 + g^A\right)^{1-\phi} = 1 + n.$$

Then, from a similar procedure in deriving Eq. (9.9), we obtain

[14] It depends on the era on which we focus, though. In the eighteenth century after the Industrial Revolution, the world population and output start to rise explosively, where population size and output growth have a positive correlation. However, the reverse causality could be true, i.e., rapid growth may result in more capacity to increase the population.

$$g^A \approx \frac{n}{1-\phi}.$$

Moreover, since per-capita real GDP grows at the same rate of g^A, economic growth depends not on population size but its growth rate, n.

This modification successfully removes the scale effect. However, it erases the R&D policy implication obtained in the original model. Because the growth rate is determined by population growth rate, a policy promoting R&D activity does not increase the growth rate in the long run, while it leaves short-run impacts on the number of researchers and outputs. Any increase in the policy-promoted research outcomes will be offset by the difficulty in developing more complex R&D projects, leaving no impact on the growth rate.

9.4 Other Factors: Look Inside of A_t more deeply

In this section, we discuss three factors other than technology that construct TFP.

9.4.1 Education and Human Capital

The level of education of the people involved in the labor is one of the important factors that determines production efficiency. Before we look at the overall productivity of a country, let us consider the productivity of individual workers. In the first place, why are you reading this and why are you spending your time and paying for your education? It is probably because there is a return from education. The returns may not always be translatable into money, but there is no denying that getting the job you want and increasing your chances of earning a higher income are important returns. Why do firms pay you a high wage? It is because your skills are enough to produce efficiently. Education increases productivity at the individual level.

Figure 9.11 shows a scatter plot of the average level of education (years of schooling) and real GDP growth rates in each country,[15] showing a clear positive correlation. As with the investment in physical capital, investment in education is expected to contribute to economic growth by improving *human capital* and raising productivity. Let us formulate this situation in a simple model to see the link between education and growth.

The production function in this context is

$$Y_t = K_t^{\alpha} (u H_t)^{1-\alpha}, \tag{9.12}$$

where H_t represents human capital and u is the share that human capital employed in the production sector. The rest of human capital, $(1-u)\,H_t$, goes to the education sector, or school teachers, that contributes human capital accumulation. Suppose that human capital accumulates according to

$$H_{t+1} - H_t = \phi(1-u)H_t,$$

where $\phi > 0$ is the efficiency in the education sector.

In this economy, for a given u, the growth rate of human capital is

$$g = \phi(1-u). \tag{9.13}$$

This human capital growth rate turns out the growth rate of the economy. Let us see how it comes. Similar to the growth rate relationship derived at growth accounting in Sect. 9.2.3, we have

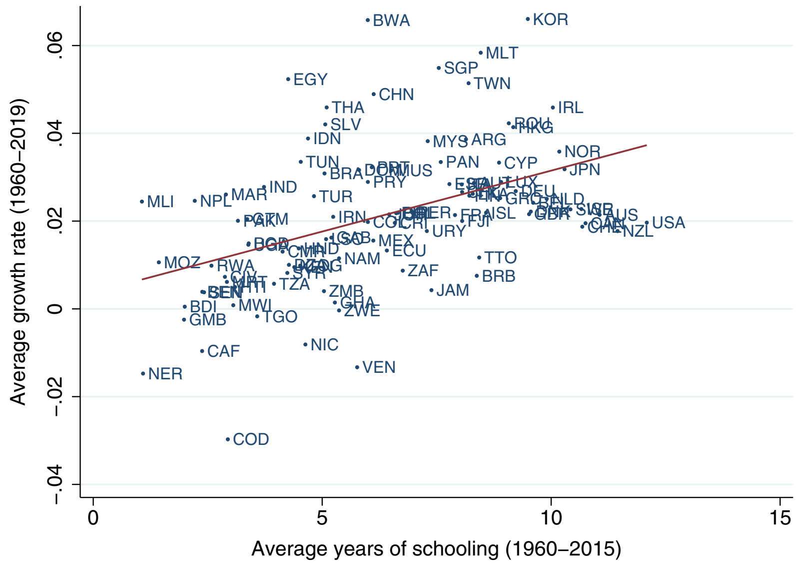
$$g^Y = \alpha g^K + (1-\alpha)g,$$

for a constant u. Because the real output and physical capital should have the same growth rates,[16]

[15] Data on education are from Barro-Lee Education Attainment Data, which are available from http://www.barrolee.com.

[16] From the national income identity, $Y_t = C_t + I_t$. To keep the balance, these three variables must have the same growth rate. Further, capital accumulation equation $K_{t+1} = I_t + (1-\delta)K_t$ implies that K_t and I_t also have the same growth rate. Therefore, $g^Y = g^C = g^I = g^K$ on a balanced growth path.

Fig. 9.11 Growth and education. *Source* PWT10.0, Barro-Lee Education Attainment Data



we have $g^Y = g^K = g$. All growing variables have identical growth rates.

The balanced growth implies that

$$\frac{H_t}{K_t} = \text{constant, say } \hat{A}$$

because the numerator and denominator change at the same rate. Using this constant $\hat{A}$ with the production function, (9.12), we obtain

$$Y_t = K_t^{\alpha}\left(\hat{A}u\right)^{1-\alpha} K_t^{1-\alpha} = \left(\hat{A}u\right)^{1-\alpha} K_t.$$

In other words, production in this economy shows a constant marginal product of physical capital on a balanced growth path, unlike in the Solow model. The Solow model investment curve depicted in Fig. 9.6 has a curvature because the marginal product of capital decreases with the capital level. In the current human capital model, the diminishing marginal product of physical capital is offset by the human capital accumulation to keep the marginal product of physical capital at constant $\left(\hat{A}u\right)^{1-\alpha}$. No matter how much is accumulated, the marginal value of capital does not fall, so the economy will continue to grow. Importantly, when more human capital is employed in the education sector, the growth rate is higher.

9.4.2 Institution

Differences in productivity among nations that cannot be explained by the production factor endowments or technology are also created by differences in institutions. At the beginning of their book, Acemoglu and Robinson [1] talk about a region divided by the artificially drawn border between the United States and Mexico. Originally, there was little difference between the north and south of the border, and similar people lived similar lives. However, 100 years after the border was drawn, there appeared a marked difference in the standard of living across the border. The gap in North and South Korea is another example. The border between the two countries was artificially drawn for political reasons due to the Korean War, and there was no intrinsic difference. Seventy years later, however, the difference in wealth between them is enormous.

Such artificial borders are grand social experiments that give us insights. If there is a big difference between two countries that are not different by birth, the cause is the environment in which they grew up. In other words, the laws, rules, political systems, and customs of the countries to which the residents happen to belong are of decisive importance. Are private property rights guaranteed there? Does it allow for free market transactions? Do successful entrepreneurs get paid what they deserve? What kind of education system does it have? How well developed is its social infrastructure? Is its political system democratic?

This argument suggests that some part of TFP, A_t, should be explained by institutions. A more efficient institution results in higher A_t, leading to a greater real output and possibly real growth rate. However, it is not easy to pinpoint what exactly is good and what is bad in the institutions. It is not necessarily true that transplanting the institutions of frontier economies, such as the United States, directly to developing countries will work. It is easier said than done.

9.4.3 Misallocation

One of the most important findings in recent economic growth studies is the impact of *misallocation* of resources on aggregate productivity. Suppose that there are two types of firms operating in the market: One is highly productive and the other is less. Then, it seems efficient to transfer resources employed by low-productivity firms to high-productivity firms. However, such reallocation could not smoothly occur in the market because we observe wide productivity dispersion across firms even within narrowly defined industries. When the misallocation of resources significantly reduces aggregate productivity, policy interventions that promote the reallocation of resources are desirable to improve people's well-being.

Hsieh and Klenow [6] is the seminal work to measure the degree of misallocation. It should be noted that simple observation of productivity dispersion is not an evidence for misallocation. The coexistence of large high-productivity firms and small low-productivity firms may be efficient because of declining marginal products and capacity constraints such as plant size. To quantify misallocation inefficiency, they consider "revenue" productivity instead of the usual TFP, which is coined as TFPR.

The logic is simple and interesting. Suppose that a firm has the production function of $Y = AL$, where A is the firm-level TFP and L is employment, hired at the wage rate of w. The cost to produce one unit of goods is w/A. If this firm determines its price with some markup margin, at the rate of $m \geq 1$, the price of the goods is $P = mw/A$. Then, the TFPR of this firm is

$$\text{TFPR} = \frac{PY}{L} = PA = mw.$$

Therefore, TFPR is independent of A. This result holds even with more general production function such as the Cobb–Douglas type with physical capital as in Eq. (9.3).

This simple calculation implies that all firms should have the common TFPR in theory after controlling markups and wages. Then, if we find a dispersion in TFPR, some wedge exists to generate a gap from the theoretical outcome. Based on this logic, Hsieh and Klenow [6] define the degree of misallocation as the observed dispersion in TFPR. According to their estimates, China and India have higher degrees of misallocation compared to the United States in the manufacturing industries. They also estimate the aggregate productivity of both countries when they have the same degree of misallocation as the United States. The results show that aggregate productivity is expected to increase by 30–50% in China and 40–60% in India, strikingly large numbers.

Reducing misallocation of resources across firms may have a significant impact on the aggregate economy. However, designing a reallocation policy is not simple because the sources of misallocation can be diverse. Adjustment costs such as firing costs would make reallocation slow. Protective policy for small firms would matter. The institution discussed in the previous subsection also matters. Taxation, financial constraint, or any distortions may affect the degree of misallocation in one country. So far, there is no consensus on the most important factor to explain misallocation. Rather, the main source seems different across countries and periods.

9.5 Conclusion

A country does not become rich overnight, and when it starts, the process of steady growth depends largely on historical circumstances. So, it is natural that there are variations in the level of economic wealth or real GDP per capita. The more important question is whether poor countries will turn into rich countries, that is, whether a poor country attains rapid growth and will catch up with the group of rich countries or not. To catch up with and hopefully overtake rich countries in the long run, poor countries need to achieve sustained economic growth rather than a temporary hike in the GDP levels. If a poor country has a growth rate that is 2% higher than a rich country that initially had twice the GDP, it will take 35 years to catch up. If the growth rate gap is 5% instead, it will only take about 14 years. This is not just a play on numbers. It is what actually happened in Japan in the 1960s and in China since the 1990s.

In this chapter, we have outlined the typical mechanisms of economic growth in as simple a model as possible while sorting out the facts related to economic growth. We have covered the accumulation of physical and human capital, technological progress, institutions, and misallocation, but which factors constitute the main problems will vary depending on the country being addressed. Since policies for economic growth will vary accordingly, we must first carefully observe the conditions of the country or region we are dealing with. In this sense, this chapter can be seen as providing a list of points to pay attentions to.

However, there are other factors that we could not cover in this chapter due to space limitations. In particular, trade and cross-border technology transfer are important in international economic interdependence. Trade with technologically advanced countries and direct investments from them cause an influx of ideas and technology to developing countries. Technology adoption and learning through imitation are typical steps in catching up.[17]

Finally, having clarified the causes of economic growth throughout this chapter, we should also remark the consequences of economic growth. Increased GDP leads to higher consumption and living standards, but thriving economic activity places a greater burden on the global environment. We need to consider the balance between economic growth and the environment from multiple perspectives. There is also the issue of inequality: Even if the size of GDP expands, not everyone will necessarily benefit from it. We must always pay attention to the distribution of wealth to ensure that economic growth does not widen the gap and leave some people behind.

References

[1] Acemoglu D, Robinson JA (2012) Why nations fail: the origins of power, prosperity, and poverty. Currency
[2] Baldwin R (2016) The great convergence: information technology and the new globalization. Harvard University Press
[3] Banerjee AV, Duflo E (2011) Poor economics: a radical rethinking of the way to fight global poverty. PublicAffairs
[4] Boldrin M (2008) Against intellectual monopoly. Cambridge University Press
[5] Groningen Growth and Development Centre (2013) National accounts in PWT8.0. University of Groningen
[6] Hsieh CT, Klenow PJ (2009) Misallocation and manufacturing TFP in China and India. Q J Econ 124(4):1403–1448
[7] Jaffe AB, Lerner J (2007) Innovation and its discontents: how our broken patent system is endangering innovation and progress, and what to do about it. Princeton University Press
[8] Jones CI, Williams JC (1998) Measuring the social return to R&D. Q J Econ 113(4):1119–1135

[17] See Baldwin [2] for arguments about trade, global supply chains, and international convergence.