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Macroeconomics

Long Term Economic Growth

Contents:

Introduction

Growth in U.S. real GDP has averaged 2.5% per year since World War II (and 3.5% per year since 1995). Let's try to explain this growth, since long term economic growth is the key to higher material living standards for future generations.

Growth Accounting

Recall that we theorized that a country's real GDP depends upon three things:
- --Amount of labor available
- --Amount of capital available
- --Total factor productivity

Well, growth accounting stipulates that long term GDP growth depends upon three things
- --rate of growth of the labor supply
- --rate of growth of the capital stock
- --rate of growth of total factor productivity

Let's get a bit more specific. The **growth accounting equation** is on the next page:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + a_N \frac{\Delta N}{N} + a_K \frac{\Delta K}{K}$$

If you like calculus, then you can see that the growth accounting equation is the total derivative of the production function

What are these weird symbols?

$\frac{\Delta Y}{Y}$ is the change in real GDP divided by the total amount of real GDP. This is equal to the percentage change in real GDP—the *growth rate of real GDP*.

$\frac{\Delta A}{A}$ is the change in total factor productivity divided by the level of total factor productivity. This is equal to the percentage change in total factor productivity—the *rate of productivity growth*.

$\frac{\Delta N}{N}$ is the change in the labor supply divided by the total labor supply. This is equal to the percentage change in the labor supply—the *growth rate of the labor supply*.

$\frac{\Delta K}{K}$ is the change in the capital stock divided by the total amount capital. This is equal to the percentage change in the capital stock—the *growth rate of capital*.

$\mathbf{a_N}$ is called the *elasticity of output with respect to labor*. It equals the percentage change in real GDP divided by the percentage change in the labor supply

$\mathbf{a_K}$ is called the *elasticity of output with respect to capital*. It equals the percentage change in real GDP divided by the percentage change in capital.

<u>Application of the growth accounting equation to the United States</u>

Suppose we believe that

--the productivity growth rate for the coming decade will average 2.5% per year.
--the labor supply will grow at 1% per year on average
--the capital stock will grow at 2% per year on average
--a_N will be .7
--a_K will be .3

Then our estimate of the average annual growth rate of real GDP in the U.S. over the next decade is:

average annual growth rate of real GDP = 2.5% + .7(1%) + .3(2%) = 3.8% per year

Warning! Growth accounting equation is very bad at short term forecasts.

The best use of the growth accounting forecast is for long term forecasts such as the one we just did for the U.S. for the coming decade. It is very bad to use it for short term forecasts, such as to try to predict GDP growth for the coming year or two. This is because there are loads of other things that can affect GDP growth in the short term. (We'll discuss short term economic fluctuations later in the semester.)

Productivity and the Information Technology Age

From 1995-2000 the past 5 total factor productivity has grown at very high rates in the U.S. This year, productivity will grow at a slower rate.

Most economists attribute the fast pace in productivity growth to innovations in technology and communications.

The high productivity growth of recent years has allowed our economy to grow quickly over recent years.

Let's hope that productivity continues to grow at a fast clip. (Unfortunately, economists are very bad at forecasting how fast productivity will grow.)

Strategies to increase the growth rate of real GDP

The growth accounting equation gives us hints as to things that would increase the long term growth rate of real GDP. Here are some examples:

1. Increase the rate of productivity growth

How? Good question. Much controversy surrounds this issue. Most economists believe that free markets and free trade lead to the best innovation and application of technology. A few economists, however, believe that government intervention can lead to higher rates of productivity growth. Certainly a better-educated workforce is a more productive workforce; theories to improve education abound and are beyond my area of expertise and beyond the scope of the course.

2. Increase the growth rate of the labor supply.

Though this will lead to higher total GDP, it will not necessarily lead to higher GDP *per citizen*, unless the labor force participation rate rises. And though this will lead to higher material living standards, it will result in a sacrifice of leisure time that may not be desirable.

3. Increase the growth rate of the capital stock

Recall that investment increases the capital stock, so techniques that increase investment will increase the growth rate of the capital stock. Recall also that in a large open economy, an increase in national savings (achieved for example by raising taxes or reducing government spending) can lead to higher investment.

Notice the tradeoff between the short term and the long term. If the present generation accepts higher taxes and lower government benefits, then future generations may be better off through higher long term growth.

The Solow Growth Model

We now take a look at a very popular model of economic growth, developed in the 1950s by Nobel Prize winning economist Robert Solow.

We shall develop a version of the model with no government or foreign trade. (Why? To avoid complexity.)

There are a lot of symbols that go into this model. Let's list them all below:

C	consumption
c	consumption per worker = C/N
d	depreciation rate of the capital stock
I	investment
K	size of the capital stock
k	capital per worker = K/N
N	size of the labor supply
n	growth rate of the labor supply
S	national savings
s	the national savings rate = S/Y
t	a subscript used to denote year "t"
Y	real GDP
y	real GDP per worker = Y/N

Now here are some fundamental equations that make up the model:

$Y_t = f(N_t,K_t)$ ←total GDP depends upon the total amount of capital and labor

$y_t = f(k_t)$ ←GDP per worker depends upon the amount of capital per worker

$Y_t = C_t + I_t$ ←GDP can be consumed or used for investment

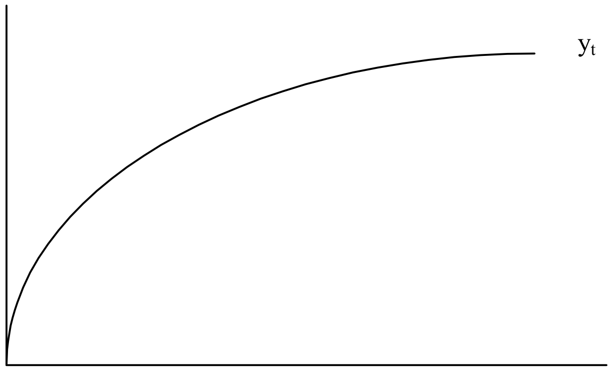
$sY_t = S_t$ ←national savings is a fraction of GDP

sy_t = savings per worker

$S_t = I_t$ ←loanable funds must equal investment

$K_{t+1} = K_t – dK_t + I_t$ ←Next year's capital stock equals last year's, minus depreciation, plus investment

Although all of those equations are fascinating, the most important one is probably the second one, which relates output per worker to the amount of capital per worker. Let's graph what that relationship looks like on the next page:



<u>A **steady state**:</u>
An important concept in the Solow model is a steady state. This is a stable situation in which capital per worker neither rises nor falls over time—k stays constant, year after year.

<u>Determining a steady state:</u>
Under what conditions will capital per worker stay constant, year after year? This is a bit complicated, since:

--the number of workers is growing every year at rate n
--the capital stock is depreciating every year at rate d
--investment adds to the capital stock every year

Considering the above issues, a steady state is reached when investment is exactly high enough over time to:

--replace the worn out capital for the existing workers AND
--provide enough new capital for the new workers

Mathematically, this requires:

$I_t = dK_t + nK_t$ ←a steady state condition

Let's rewrite the above condition:

$I_t = (d + n)K_t$ in a steady state

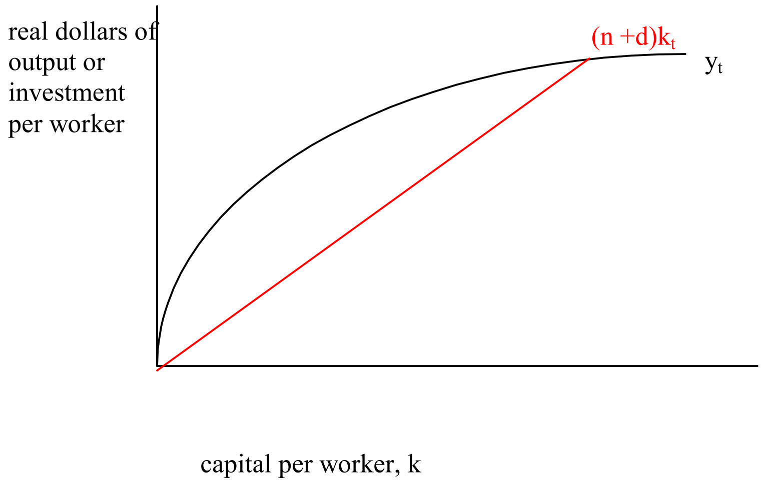
Let's rewrite the above condition, in its *per worker* version:

steady state investment per worker = $(\mathbf{d} + \mathbf{n})\mathbf{k}_t$

Now, remember, the only source of funding for this investment is from savings. Savings per worker = sy_t so in a steady state:

$sy_t = (d + n)k_t$

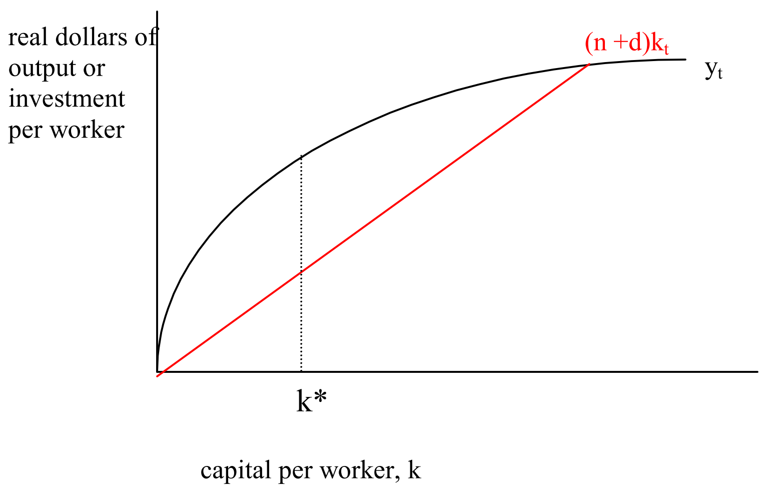
Let's graph the steady state level of investment equation, on the same graph on which we put output per worker, y_t:



The above graph is a bit tricky to interpret. Note:

--The vertical distance between the y_t curve and the investment line equals consumption! This must be true, since any y_t that is not saved is spent.

--The golden rule: The best level of savings and investment per worker is the level that results in maximum consumption. On the graph, that is the point where the distance between the y curve and the investment line is maximized, roughly as in the dashed line on the below graph:



Achieving k*--the best level of investment per worker

Since this is a closed economy, there must be exactly enough savings to fund k*.
Implications:

--If s is currently **too low** (as perhaps it is in the U.S.), then a country's citizens can increase their steady state level of consumption by increasing their savings rate. (On the graph, a country with a too low savings rate would have k to the left of k*.)

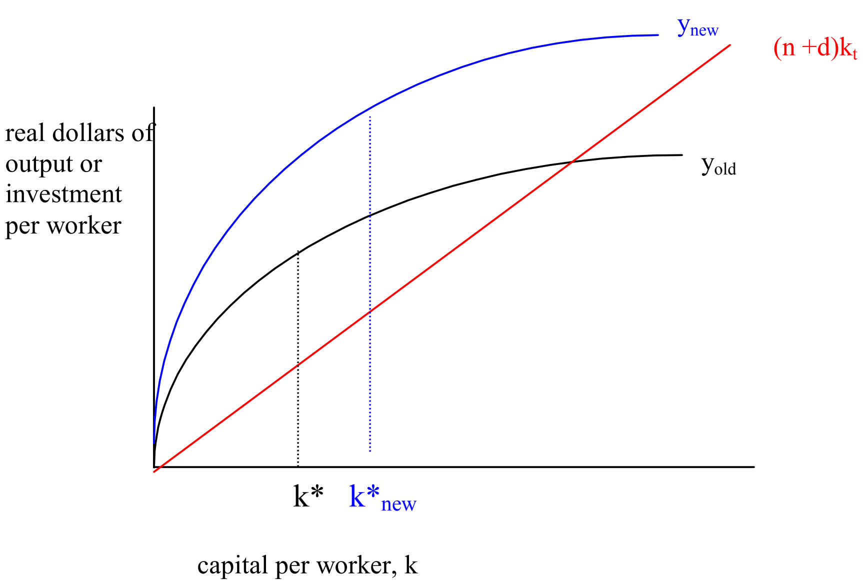
--If s is currently **too high** (as perhaps it is in Japan), then a country's citizens can increase their steady state level of consumption by decreasing their savings rate. (On the graph, a country with a too high savings rate would have k to the right of k*.)

k*--The best that can be done?

Suppose that a country's citizens are saving exactly the right amount to achieve k*. Does this mean that there is no way to further increase consumption—that the country has reached the limit of its material well being?

Well, in earlier versions of the Solow growth model, this was TRUE! But newer versions of the model include the importance of **innovation**. Innovation increases factor productivity and allows a country's material well being to advance without limit.

Here's a graph showing the effects of innovation on k* and consumption per worker.



The y curve shifts up due to innovation. Notice how the vertical distance between y_{new} and $(n+d)k^*$ has increased; this signifies higher consumption per worker.