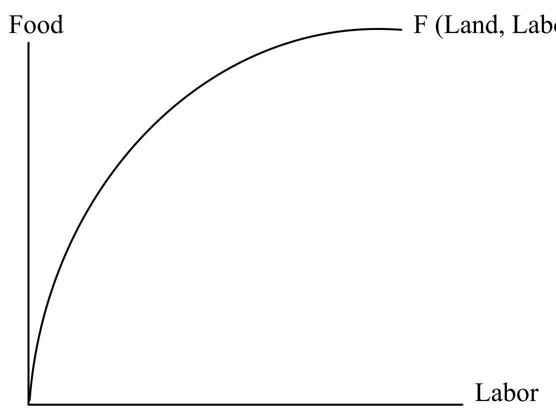
Malthusian Growth (Thomas Malthus, 1798)

Malthus noted that world population seemed to be increasing at a faster rate than agricultural production was. He was worried agricultural production couldn't keep up with population growth. He was worried economic growth would come to a screeching halt. Malthus had agricultural production in mind. When you think of real GDP, think of food. Think of population growth as an increase in the amount of labor available.

Malthus' production function has two factors, land and labor. Of particular importance in this model, is that the quantity of land is fixed. There is only so much arable land. Given a fixed quantity of land, adding labor will increase food production, but at a diminishing rate.

Also, Malthus suggested that parents would always have as many children as they could possibly support, given their real wages. If wages (incomes) increased, parents would have more children until they could just afford (to feed) the last child. You would keep having children until real wages were at subsistence levels. The only check on population growth would be starvation, disease, etc. (No one who could "afford" to have 4 children would stop at 2).

If we look at a production function, we can get a rough idea of what he had in mind. Put food (real GDP) on the vertical axis and labor on the horizontal axis. The question we can ask is this – we know production increases as we add labor, but what happens to real GDP per person?



This is easiest to see in a chart form. We calculate the marginal product of labor, and of course it diminishes as we add labor. The new addition for us is average product of labor, abbreviated APL. It is the average amount of real GDP per unit of labor. In this setting, it is the average amount of food per person (laborer).

Labor	Food	MPL	APL
1	4	4	4
2	7	3	3.5
3	9	2	3
4	10	1	2.5

We can then see, as the amount of labor increases (holding the amount of land constant), the amount of food per person decreases. Say the average person needs 3 units of food per period to survive. The addition of the third person to the population drives down real wage to a subsistence level. If the fourth laborer shows up, someone will not have enough food to survive. Starvation will occur. Someone will die. Parents will have fewer children, until the real wage is back to its subsistence level.

If however there were only 1 person alive, the real wage is high, and thus Malthus says there will be reproduction. Parents will have children until the average person has just enough to survive. Thus, there will be a limit to economic growth. There will be a tendency to a steady state level of real GDP where people barely get by. Once we get there, there would be no population growth and no growth in real GDP.

So, in a nutshell, given reproduction (whenever it could be afforded), and diminishing marginal returns to labor (because of a fixed supply of land), economic growth would come to halt, and the world would live at a subsistence level. Economics is the dismal science.

Was Malthus right?

Do we live today at a subsistence level? Nope. Where did Malthus go wrong?

First off, parents don't (and didn't even in 1798) reproduce to the point where they could just barely support their children (do you have 25 brothers and sisters?). So population didn't grow as fast as Malthus thought it would. And….

Mathus didn't include capital, but even more importantly….

Malthus didn't include technological progress. If technological progress occurs, we could have economic growth and support an ever-increasing population. We don't see the famine and starvation that his model would predict. There has of course been a great deal of technological progress in agricultural production and elsewhere. Certainly technology is very important in explaining economic growth.

Is there something here though? What's the flavor of his message?

There is a sense in which Malthus could *possibly* be right. There is a fixed amount of natural resources today. There is only so much oil, so much coal, so much phosphorous (at least that we have discovered *so far*). Is it possible that we could have a slowing or stopping of economic growth when we run out of these resources? Yes, it is possible. But is it likely?

Keep in mind that technological progress does occurs. People are innovative. Will we run out of oil? Maybe. As we're running out of oil, will the price of oil increase? Certainly. But would the increased price of oil spur innovation in development of viable alternatives to oil for our needs (solar power – wind power)? Would it lead to inventing more efficient methods of extracting oil? Would it spur innovation in drilling technology to tap into previously unattainable deposits? Yep.

Don't forget how the price system helps to allocate scarce resources. As resources become scarce, their price will increase. This will spur innovation. Innovation is technological progress. A price increase in oil would increase the return to developing alternatives. We can develop solar power, wind power, etc. Given the prices we see today, it makes sense to just gobble up cheap oil. This would change if the price of oil increases. The Malthusian story seems a bit weak. Some people buy into this.

The (sort of) famous bet I spoke of

Environmentalist Paul Ehrlich - a long-time forecaster of gloom, doom, and the running out of natural resources. Thus, as we run out of non-renewable natural resources, the prices of resources will rise.

Economist Julian Simon – a sensible man, who knows that the price of non-renewable natural resources had in the past actually fallen. Thus, the price of resources will fall over time. Innovation in extraction, developing substitutes, etc….

The bet: Ehrlich can pick his favorite 5 non-renewable resources, in any quantity such that the total spent was $1000 in 1980. In 1990, they look at the real prices (adjusted for inflation). That if the prices of these goods rise faster than inflation, Ehrlich wins. If not Simon wins. The loser pays the winner the difference.

(As an interesting side-bar, Simon could lose an infinite amount of money, while the most Ehrlich could lose was $1000).

Ehrlich accepts the bet and chose copper, chrome, nickel, tin, and tungsten.

By 1990, the relative prices of all five metals had fallen below their levels in 1980. Ehrlich owed Simon $567.07, and paid up.

(Despite a decade of general rising prices, Simon would have won even if there had been no adjustment for inflation. The nominal prices had actually fallen.)

In a smartass-like move(?), like many economists(?), Simon offered the same bet again from 1990 to 2000 and offered to up the ante to $20,000, but Ehrlich was not interested.

While I have not read it, for some kicks you can check out Ehrlich's book, The End of Affluence, where apparently he warns of

"a nutritional disaster that seems likely to overtake humanity in the 1970s (or at the latest, in the 1980s),"

Solow Growth – the better stuff

We'll take a look at a model of economic growth called Solow growth. One of the things that I hope you're getting a handle on is the following: the amount of capital you have on hand at any time (the capital stock) is going to determine the level of GDP.

Think back to our classical model (the one with the production function and the market for labor). A larger capital stock (adding capital) will shift up the production function. Thus you'll get a larger level of real GDP for the same amount of labor. In addition, as adding capital makes workers more productive, there will be an increase in the demand for labor.

Thus it seems, and it is correct, that the capital stock is going to be important in explaining economic growth. This is what the Solow growth model has in mind.

So the questions are – does increasing the capital stock lead to economic growth? Do economies that save and invest more grow faster and bigger than economies that save less? Can economic growth caused by adding capital last forever? I know you can hardly wait. Read on.

Stocks vs. flows

Think of a bathtub filled with water. Think of one that is drawn better than the one I drew in class. Think the total amount of water in the bathtub at any one time as "the stock of water". Water can flow into the bathtub (a flow), causing the water to rise. Water can also flow out of the bathtub (down the drain), causing the water level to fall. If the flow into the bathtub is larger than the flow out of the bathtub, the water level (the stock) will rise. Doesn't economics make bath-time lots of fun? Rubber duckie…

Now that you know how to fill and drain a bathtub, let's take the stock vs. flow story and talk about the stock of capital. Remember, K, the stock of capital, is the total amount of capital available to the economy at any given time.

The flow of new capital is called Investment, I. It comes from the market for loans. Remember the market for loans? At the equilibrium real interest rate, Savings = Investment = Loans. Remember, investment is literally spending by private companies to create new capital. It is new spending on tools, factories, etc. The more investment we have today, the more capital we'll have tomorrow. While it's not super important here, we'll assume it takes a year from the time we borrow the money and start building the factory until we can actually use the new capital. So investment today makes new capital tomorrow.

What is the flow out of the bathtub? I drive a beater car. It is not in the same mechanical condition as when it came of the assembly line (at the hands of some clearly hungover autoworker). Clearly, it is not the same car it was when the original owner bought it 10 years ago. Capital depreciates over time. Some of it wears out. We call the amount of capital that wears out the amount of depreciation.

Hmmn, we have investment (new capital) flowing in, and depreciation flowing out. What would the expression for the change in the capital stock in any period?

ΔK = Investment – Deprecation   where K = the capital stock

In words, the change in the capital stock is equal to the amount of investment minus the amount of deprecation.

Assumptions of the Solow model

The Solow growth model makes a nice assumption about the amount of investment an economy makes to keep things simple. It assumes that the economy as a whole decides to save and investment a constant fraction of their income (or output). Letting s stand for that fraction (think of this as the fraction of the economy's income that is saved), the amount of investment is given by

Investment = $s * Y$ where Y = GDP

How much capital depreciates every year? Again, a nice assumption that some constant fraction of the capital stock wears out every year is made. Let d stand for the fraction of capital that wears out every period, then we have

Depreciation = $d * K$

What then in the expression for the change in the capital stock in any period?

$\Delta K = s * Y – d* K$

Remember this equation is important.

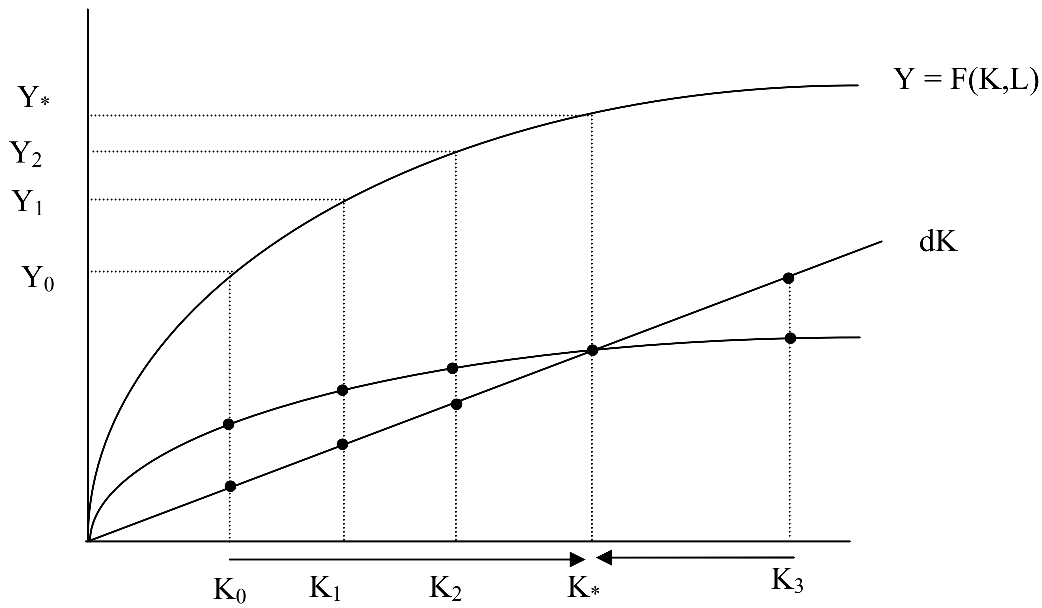
Shall we make some other simplifying assumptions?

Sure why not. Let's assume there is a constant amount of labor available for our economy. Thus, no matter how much capital we decide to have, there are, say 1000 workers. Thus, there is no population growth to worry about here.

What's in our production function then? Output is a function of capital and labor, with the amount of labor fixed. This is different that we usually do it. Usually we assume that the amount of capital is fixed, and thus adding labor runs into diminishing marginal product of labor.

Here we do the opposite. Given a fixed quantity of labor, adding capital will increase output, but at a decreasing rate. This is a diminishing marginal product of capital. The production function is drawn similarly, but it is capital we vary on the x-axis.

A picture is worth a 1000 words



<u>Can I have a couple hundred of those words please?</u>

How do I draw the curves?

The production function

Output is a function of the amount of capital and labor I have, with the amount of labor assumed fixed. Thus, the only way to get more output (GDP) is to have more capital. So, at high levels of capital we get lots of GDP, at low levels of capital, we get small GDP, ceteris paribus.

The Investment curve

Investment = s * Y. Remember, investment is a constant fraction of GDP. Thus, we need to draw a curve that is some constant fraction of GDP. But the production function is a picture of the amount of Y you get. Think about drawing a curve that is half as big as GDP (s = 0.5). Well, that of course is a curve that everywhere is half as tall as the production function. For s = 0.2, 0.1, or any other level, it will have the same general shape as the production function, just "squished down".

The Depreciation curve

Depreciation = d * K. As there is a constant fraction of the capital stock that is depreciating every year, the amount of depreciation is just a straight line beginning at the origin with a slope of d. Say d = 0.03. This means 3% of the capital wears out every year. The more capital we have, the more wears out. See the picture above.

<u>So what?</u>

Consider if the economy wakes up one morning with K_0 units of capital. Looking at the investment curve tells you how much new capital will be created next period. Looking the deprecation curve tells you how much existing capital will wear out and thus be gone next period. At K_0, investment exceeds depreciation, or sY is bigger than dK. So, it must be the case that $\Delta K > 0$. Or in other words, since we're adding more new capital than is wearing out, we'll have more capital next period. That bathtub is filling. Thus, tomorrow we'll be at a higher level of capital, say K_1.

What happens at K_1? Same story. Investment is larger than deprecation, so the capital stock increases, say to K_2.

What happens at K_2? Ditto.

When does it stop? Imagine we get out to K*. The amount of investment is exactly equal to the amount of depreciation. The economy is creating just enough new capital to replace the amount that wears out. sY = dK. $\Delta K = 0$. We'll be at K* again tomorrow, and the next day, …. We call K* the steady state level of capital. If we ever get to K*, we'll stay there indefinitely.

<u>Hey, this is supposed to be an economic growth model. What happens to GDP?</u>

As we accumulate capital, GDP grows. Notice as we go from K_0 to K_1 to K_2 to K* we also go from Y_0 to Y_1 to Y_2 to Y*. This is economic growth. But when we get stuck at K*, we get stuck at Y*. Notice growth seems to slow down as we get closer to K* (and hence Y*), and then eventually stops.

<u>What then is the big picture?</u>

Increasing the capital stock will lead to economic growth.

But, ceteris paribus, eventually this economic growth (caused by increases in the capital stock) must slow and eventually stop.

<u>What does this model miss?</u>

Population.

Recollect this model assumed a fixed population. Surely increases in population (increases in the labor force) will cause more economic growth than this model says. But take it without proof for me, that while increase in the labor force can cause economic growth in the level of GDP, it will not cause increase in GDP per capita (per person).

Technology.

This is the big one here. The Solow model says that eventually growth must slow down and stop. But has it? No, the economy has been growing for a long time and show no indication of slowing or stopping. Could it be that we just haven't gotten to K*? Maybe, but if there is technological progress, this shifts up the production function. This in and of itself causes higher GDP. In addition, if the economy stays at the same s (and the now higher production function), the sY curve shifts up. This leads to a higher K*, and even more economic growth.

So, if we get continuous technological progress, K* is sliding out to the right every year, and the production function is shifting up every year. Thus we're chasing after K*, but it's a moving target. We can get economic growth forever.

<u>Gosh, I was wondering if there is some fun tinkering I could do that would make nice test questions?</u>

Exercise #1: Draw the picture I have above. Now, increase the saving rate, s, of the economy, and see what happens to K* and Y*.

Exercise #2: Shift up the production function, and keep s the same. Draw your new investment curve (sY) – it should shift up. What happens to K* and Y*.

Exercise #3: Based on your answers to the first exercise above, it sounds like increasing the saving rate is a darn good idea. Why might this not be the case? Say we save 100% of the economy's income? Is there any income left to spend on food? Do you want to save 90% of your income? Or even 80%?

Exercise #4: Go to the website. Crack open the Solow Growth spreadsheet. Follow the instructions within. I do all sorts of calculations and draw the graphs for you. You should be able to get a definitive answer to Exercise #3. What savings rate, s, is the best for the economy? Try 0.1, 0.2, 0.3,…..0.9, 1. Hmmm, could this be a test question. I wonder?!?!?!?

<u>One more thing for the super interested</u>

Look at that picture again. Check out K_3. Suppose we wake up with this level of capital, this is above the steady state level of capital. What will happen?

This certainly begs the questions of how we got there in the first place (beat's me), but nonetheless, at K_3, the amount of depreciation exceeds the amount of investment. That is, capital is wearing out faster than it is being replaced. Thus, the capital stock will fall ($\Delta K < 0$), and there will be a lower capital stock tomorrow. This will continue until we arrive at K*. This seems like as good a place as there will ever be to include one of my favorite all time quotes. "A fool and their money are soon parted. What I want to know is how they got together in the first place."

<u>What should I read?</u>

Again, just the notes here.

My website - that Excel spreadsheet.