TA SECTION 4th of DECEMBER 1997
THE SOLOW GROWTH MODEL: A REVIEW and
TECHNOLOGICAL PROGRESS; SOME CONSIDERATIONS ON
THE CONSEQUENCES OF TECHNOLOGICAL PROGRESS ON
THE LABOR MARKET.

1. OBJECTIVE

In this last TA section, we briefly review the \textit{Solow Growth Model} and we introduce technological progress in it. We are going to see that technological progress has been/is the main source of growth. Also, we make some considerations on the consequences of technological progress on the labor market.

ISSUES:

- How can we explain growth over time ?
- How can we explain differences in growth and GDP per capita ?
- What factors might influence growth ?
  - Savings (Capital accumulation), Population growth, \textit{Technological progress}.

2. A QUICK REVIEW OF THE MODEL WITH CAPITAL ACCUMULATION AND POPULATION GROWTH

- WE ARE LOOKING AT ECONOMIC ACTIVITY OVER LONGER PERIODS OF TIME.
- WE LOOK AT TREND AND DO NOT CARE ABOUT FLUCTUATIONS ANYMORE.
- THE ANALYSIS IS BASED ON A SINGLE MODEL: THE \textit{SOLOW GROWTH MODEL}.

So far, we considered capital accumulation and population growth.

The model was the following:

\[
\begin{align*}
y &= f(k), \text{ where } \quad y = Y/L \text{ and } k = K/L \\
\Delta k &= s f(k) - (\delta+n)k, \text{ (cap. accumulation equation)}
\end{align*}
\]

where $\delta$-rate of capital depreciation, $n$- population growth rate, $s$- saving rate.
MAIN ISSUES TREATED:

• Determination of the steady-state (SS)(the Long-run eq. the economy will tend to, in the absence of any shocks, given specific values for $\delta$, s and n).

Defined by $\Delta k = 0$

Investment is balancing out loss of capital stock due to depreciation and need to provide capital to new workers.

In SS, k and y are not changing but K and Y are growing at a rate of n.

• The importance of the saving rate and the population growth rate: How do changes in s and n impact on the SS?

• For each saving rate and for each population growth rate, there is a different SS capital stock and output to which the economy will converge over time.
• The saving rate has no effect on the growth rate in the LR, while a change in n has an effect on the growth rate of Y and K. An increase in the saving rate will lead to higher growth for some time but not forever (capital accumulation cannot by itself sustain growth).

• The Golden-Rule saving rate, capital stock per worker and output per worker

The GR saving rate is the saving rate that maximizes steady-state consumption.

Given by the condition $f'(k_{GR}) = \delta + n$

This is NOT the steady state to which the economy converges. It is a specific steady-state (with specific values for s, k and y) where steady-state consumption (c) is maximized.
3. TECHNOLOGICAL PROGRESS AND GROWTH

We now focus on technological progress, its determinants and its implications for growth.

The determinants of Technological Progress

Most technological progress in modern economies is the outcome of firms’ research and development (R&D) activities. (Industrial R&D expenditures account for between 2 and 3% of GDP in each of the major rich countries).

Two main factors determine the level of R&D and the rate of technological progress:

- The fertility of research: How spending on R&D translates into new ideas and new products.
- The appropriability of research results: appropriability captures the extent to which firms benefit from the result of their R&D. If firms cannot appropriate the profits from the development of new products, they will not engage in R&D and technological progress will be slow.

Introducing technological progress into the Solow growth model

We are going to extend the Solow growth model to allow for technological progress.

The new production function is:

$$Y = F(K, LE)$$

where, E- state of technology, K-Aggregate capital stock, L- Labor.

LE is called effective labor.

This equation states that production depends on capital and on effective labor. We can think of technological progress in two equivalent ways:

- Given the existing capital stock, technological progress reduces the number of workers needed to achieve a given amount of output.
- Technological progress increases LE, the amount of effective labor in the economy. If the state of the technology doubles, it is as if the economy had twice as many workers.

Same technical assumptions as before:

- CRS: If we double K and LE, Y also doubles;
- Diminishing marginal products: $$\frac{dF}{dK}$$ and $$\frac{dF}{d(LE)}$$ are decreasing in K and LE, respectively.
Same simplification as before: we are going to look at output, capital and consumption per effective worker.

Define, \( y = Y/(LE) \), \( k = K/(LE) \) and \( c = C/(LE) \)

As before, we have \( y = f(k) \) \[1\], but with the new definitions for \( y \) and \( k \).

\[
\begin{align*}
\text{y} & \quad \text{f(k)} \\
\text{k} & \quad \text{y}
\end{align*}
\]

Capital accumulation equation:

As before, \( I = sY \) and \( i = I/(LE) = sY/(LE) = sf(k) \)

In the steady-state, we want to keep a given level of capital per effective worker (\( k = K/(LE) \)).

Let \( g_e \) be the technological growth rate.

Now the amount of investment required for balanced growth (variables per effective labor constant over time in steady-state), is \((\delta + n + g_e) K\). This is so because new capital is needed not just to replace depreciated capital, but also to provide new effective workers the same level of capital per effective worker than their predecessors had. The former requires \( \delta K \) new investment per period, while the latter requires \((n + g_e)K\) new units of capital per period.

In this way, our equation for capital accumulation becomes:

\[
\Delta k = s f(k) - (\delta + n + g_e)k \quad \text{[2]}
\]

Notice that this is the same equation as before, with an additional factor \((g_e)\) and a new interpretation for the lowercase letters variables.

Everything works as before considering the new set of two equations describing our system, \[1\] and \[2\].

The Steady state:

Given by \( \Delta k = 0 \), or \( sf(k) = (\delta + n + g_e) \)

Graphically,
In the LR, k and y reach a constant level. Their growth rate is zero.

In steady-state, in this economy, what is constant is not output but rather output per effective labor.

Result: In SS, the growth rate of output and the growth rate of capital (and also the growth rate of consumption) is equal \( n + g_E \). The growth rate is independent of the saving rate.

\[
\text{Growth rate (X,Y)} \approx \text{Growth rate (X)} + \text{Growth rate (Y)}
\]

Since \( Y = y \cdot L \cdot E \), growth rate (Y) = growth rate (y) + growth rate (L) + growth rate (E) = \( 0 + n + g_E \)

Same thing for \( K = k \cdot L \cdot E \).

The standard of living is measured by \( Y/L \).
Since \( Y/L = yE \), then the growth rate of the standard of living is \( g_E \).

The importance of the saving rate and the technological growth rate: How do changes in s and \( g_E \) impact on the SS?

Example 1: The effects of the saving rate (increase in s)
Example 2: The effects of \( g_E \) \((\text{an increase in } g_E)\)

The Golden Rule:

The method is the same as before. By maximizing consumption per effective worker in steady state, we obtain:

1. Capital stock
   \[ f'(k_{GR}) = \delta + n + g_E \]

2. Saving rate
   \[ s_{GR} f(k_{GR}) = (\delta + n + g_E)k_{GR} \]
4. THE FACTS OF GROWTH REVISITED

Three main facts identified before:

- Sustained growth, especially from 1950 to the mid-1970s
- Slowdown in growth since the mid-1970s
- Convergence, or the fact that countries that were further behind have been growing faster, closing the gap between them and the US.

Let’s use our theory to analyze these facts.

Suppose an economy is growing unusually fast - either in relation to its own growth in the past, or in relation to growth in other countries. Our theory (assuming there is no population growth) suggests that this fast growth may be due to one of two causes:

1. Higher rate of technological progress.
2. Adjustment to a higher level of capital per effective worker.

How can you tell which is the cause?

Look at Y/L. If (1) is the cause, Y/L should be growing at a rate $g_E$. If (2) is the cause, Y/L should be growing at a rate higher than $g_E$.

The observations have led to the following conclusions: (i) the period of high growth was marked by rapid productivity growth; (ii) the slowdown that took place beginning in the 70s was due to lower productivity growth; (iii) convergence among countries has come from faster technological progress among poorer countries.

5. THE CONSEQUENCES OF TECHNOLOGICAL PROGRESS ON THE LABOR MARKET

Technological change is not perfectly wonderful, it can cause many problems at a microeconomical level.

Basically, in the SR, it can benefit some people but hurt others:

Examples:

- Switchboard operators hurt;
- TV repair people hurt by improved TVs;
- Computer programmers benefitted by the development of computers.

With technological progress comes a complex process of job creation and job destruction. For those who lose their jobs and have to find new ones, or for those who have skills that are no longer in demand, technological progress can indeed be a curse rather than a
blessing. Some workers may suffer from prolonged unemployment and settle for lower wages when taking a new job.
This concern is of particular relevance in the US today. The last 15 to 20 years have been characterized by a decline, both relative and absolute, in the wage of low-skilled workers => increase in wage inequality whose main cause seems to be technological progress.

THE END

IT WAS FOR ME A GREAT PLEASURE TO BE YOUR TA. I WISH YOU GOODLUCK IN YOUR FUTURE. FEEL FREE TO KEEP IN TOUCH. I GUESS, BY NOW, YOU KNOW BY HEART MY E-MAIL ADDRESS (PSANTIAGO@NWU.EDU).