Technology and Economic Growth

Chapter 5

Outline

- The Growth Accounting Formula
- Endogenous Growth Theory
- Policies to Stimulate Growth
- The Neoclassical Growth Revival
- Real wages and Labor Productivity
- Productivity and the New Economy

5.1. The Growth Accounting Formula

- Framework that can be used to determine the contribution of labor, capital and technological change to economic growth:

- Rate of growth of output = technology growth + weighted rates of growth of labor and capital **(growth accounting formula)**

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \frac{0.7\Delta N}{N} + \frac{0.3\Delta K}{K}$$

Historical Growth Accounting

- The formula can be used to determine the contributions of each factor in the long-term growth in the US in the last 35 years.

Exogenous Technological Change

- Previous assumption = no technological change so $\frac{\Delta A}{A} = 0$
- If so, on the balanced growth path with N

and K growing by 1% per year $\therefore \frac{\Delta N}{N} = \frac{\Delta K}{K} = 1\%$

$$\frac{\Delta Y}{Y} = 0 + 0.7(1) + 0.3(1) = 1$$

- If K, N and Y grow at the same rate and no technological change then Y/N does not grow

Exogenous Technological Change

- But there is technological change (see formula)
- If $\frac{\Delta A}{A} = 1\ \%$ technology grows by 1% per year

our example becomes: $\frac{\Delta Y}{Y} = 1 + 0.7(1) + 0.3(1) = 2$

- Output grows by 2% per year

Exogenous Technological Change

- Even if K/N is constant, Y/N output per capita increases because of the improvement in technology
- Remember – here technological change is exogenous – increase in Y produced with given N and K input
- Question: Can technology growth be explained by endogenous factors within the model?

What have we learned?

- **If no technological change**: Y growth depends on N growth (= with K growth) which depends on population growth rate (which is given, **exogenous**)
- **If saving rate rises** – long-run Y growth rate does not increase (= growth rate of N)
- **Add technology growth** – growth rate of Y changes but it is still exogenous (determined outside of the model)

5.2.Endogenous Growth Theory

Since 1980 – Paul Romer, major contributor to growth theory

- explains technological growth rather than treating it as exogenous
- provides a theory that determines the behavior of the technology factor

A Production Function for Technology

- Increase in technology – anything that increases the quantity of output produced with the same amount of N and K
- Many things can improve technology: assembly line, increase in skill of workers (increase in human capital), etc
- Difficult to develop a model for all activities

A Production Function for Technology

- A successful approach: **ideas or inventions** produced with N and K – "invention factories" (Paul Romer)

Ex: research labs – workers produce new ideas and inventions – production measured by new "patents"

A Production Function for Technology

Production Function for technology:

$$\Delta A = T(N_{A,} K_{A,} A)$$

- Increase in technology depends on labor to produce technology, the amount of capital employed and existing stock of technology.
- Note N_a<N and K_a<K (only part of the total available)

A Production Function for Technology

- Technology is **endogenous** now
- Two properties of technology:
  - **Nonrivalry** – one person's use of technology does not limit another person's use of the same technology
  - **Partial excludability –** the inventor or owner of the technology cannot completely prevent other people from using it (unless there are patents)

Increasing the Long-Run Growth Rate

- Production of technology can be increased by investing more resources in research
- Can the growth rate of technology (and output) be permanently increased?
- Or can the growth rate of technology (and output) be increased only during a transition period, as in the Solow Growth Model (neoclassical model)?

Increasing the Long-Run Growth Rate

- The growth rate can be permanently increased in this case:

- Specific case: $\frac{\Delta A}{A} = cN_A$

$$\Delta A = cN_A A$$

- Long-run growth rate of technology depends on the number of workers in technology production

Increasing the Long-Run Growth Rate

- An increase in the share of workers doing research increases the growth rate of technology, which increases the growth rate of output

- **Increase in investment in research leads to a permanent increase in the rate of growth and not only during a transition period**

Increasing the Long-Run Growth Rate

- Difference between a permanent increase and an increase during a transitional period:
- **Technology (stock of ideas) does not have diminishing returns.**

- Higher levels of technology increase researchers' productivity, producing more technology.

- Versus Solow model: each additional unit of capital increases workers' productivity in producing more output.

Increasing the Long-Run Growth Rate

- But each additional unit of capital increases output by **a smaller amount**, while each additional unit of technology increases the production of new technology by **the same amount.**

- If diminishing returns to technology – no permanent effect on long-run growth

5.3. Policies to Stimulate Growth

- The government can influence all three determinants of growth: technological change, capital formation and labor input
- Influenced by the low rates of growth of the 1970s
- Government can encourage such activities as education and research (social benefits exceed private benefits)

Policies to Improve Technological Growth and Productivity

- The most important role for government: **education** (primary, secondary schools, and universities)
- Federal contribution to R&D declined from 1960 to 1990
- Individuals and firms choose levels of spending on education lower than the social optimum – the government offers grants and subsidies

Policies to Stimulate Capital Formation

- Government policy has historically concentrated on capital formation
- A rising capital stock adds to economic growth (see the growth formula)
- An extra 1% of capital growth adds 0.3% point to growth in output. To get an added 1% of growth in output, the capital stock would have to grow 3.3% per year.

Policies to Stimulate Capital Formation

- 1% more growth would restore growth rate from 1960s, increase living standards, and bring additional technical innovations – leading to more growth.

- Increased growth in capital stock requires increased investment spending; this occurs only if we reduce consumption, government purchases, or net exports.

Policies to Increase Labor Supply

- **Reduction in income tax rates**

- increases the incentives to work by increasing the wage

- makes people better off – which depresses labor supply

- net effect is small

- **Tax reform**

- change the marginal rates and average tax rates without changing average income

- not an incentive for leisure

Policies to Increase Labor Supply

- An extra 1% of employment growth adds 0.7% to output growth. Or, to get an added 1% of output growth, it takes 1.4% of added employment growth.

5.4 The Neoclassical Growth Revival

Technological progress – key to economic growth in both growth models: Solow and endogenous

Remember: endogenous growth theory – technological change is explained through a production function, as opposed to the Solow model where it is unexplained (exogenous).

Endogenous growth theory conclusion: The possibility of using government policy to increase the long run growth rate – increased investment in research increases the growth rate

The Neoclassical Growth Revival

- Growth rates increased in the 1980s and 1990s compared to the 1970s - increase in technological change
- We have seen that a number of policies can influence growth
- Is this evidence in favor of endogenous growth models?

The Neoclassical Growth Revival

- Gregory Mankiw and Charles Jones argue that long term growth in the U.S. is consistent with the Solow growth model.

The Neoclassical Growth Revival

- **Is the U.S. consistent with Solow growth model?**

Consider a thought experiment:

- using data through 1929, draw the straight line that provides the closest fit for the actual data
- suppose that you are an economist in 1929 trying to predict GDP per capita in 2001
- assuming that growth rates between 1929-2001 would be the same as between 1870-1929, extrapolate the same straight line to 2001
- the prediction of GDP per capita would be off by only 19%

The Neoclassical Growth Revival

- **Is the U.S. consistent with Solow growth model?**

- Between 1950-1990, the number of scientists and researchers (in the U.S.) engaged in research and development increased more than fivefold – neither the growth rate of technology nor the growth rate of output increased comparably

The evidence for the U.S. seems consistent with Solow predictions – yet this does not discard endogenous growth models – technological change must come from somewhere

5.5. Real Wages and Labor Productivity

- Real wage (w/p) = marginal product of labor in the growth model

  - measures the purchasing power of the wage, the amount of goods and services that can be bought with one hour of work – from workers' point of view

  - measures the real costs of labor input – from the employers' point of view

Real Wages and Labor Productivity

- Real wage does not fluctuate in a systematic way during recessions and booms
- Its most noticeable property is growth over time

Labor Productivity

= output per hour of labor

- **Productivity** is the amount of output produced per unit of input.
- Because labor is the most important input, productivity's most important measure is **labor productivity**
- Broader – **total factor productivity** = output per generalized unit of input (factor means **labor** or **capital**)

5.6. Productivity & The New Economy

- post-1995 acceleration in economic growth
- birth of a "new economy" dominated by high technology industries
- recession in 2001, yet the high productivity continued
- Productivity growth = increase in output per hour of labor: capital deepening, labor quality, improvements in the measurable skills of the workforce, and technological change or total factor productivity