LECTURE 8: THE FACTS OF GROWTH[*]

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Over the course of decades, the effects of long run output growth on economic welfare dominate the effects of short and medium run output fluctuations. Understanding growth is of fundamental importance for the world's poorer economies, many of which have suffered negative per capita growth rates in the postwar period. This lecture summarizes what economists know about growth. First, we describe the empirical facts about growth across a spectrum of economies in the postwar period. Second, we introduce an aggregate production function with constant returns to labor and capital jointly, but decreasing returns to each input separately. This production function implies that growth cannot be sustained by capital accumulation. Ongoing technological progress is required to sustain growth. (Assigned reading: section 10-3 of required textbook)

1 MEASURING THE STANDARD OF LIVING

We care about growth because we care about the **standard of living**. The variable we use to compare growth rates either over time or across countries is **output per person**, rather than output itself. When comparing GDP per person using exchange rate, there are two disadvantages:

- Exchange rates can vary a lot, leading to large fluctuations of the standard of living, which is obviously not the case.

- Prices of basic goods—those goods needed for survival—can vary a lot across countries. In general, the lower a country's output per person, the lower the prices of basic goods in that country.

In practice, comparisons of standards of living are corrected for the variations in exchange rates and the systematic differences in prices across countries. The resulting measures of GDP and GDP per person, constructed using a common set of prices for all countries, are called **purchasing power parity** (PPP) numbers. You can download the PPP numbers from the Penn World Tables, http://www.rug.nl/research/ggdc/data/pwt.

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2 GROWTH IN RICH COUNTRIES SINCE 1950

We look at the evolution of **output per person** (GDP divided by population, measured at PPP prices) for France, Japan, the U.K., and the U.S. since 1950 because what has happened to them is broadly representative in other advanced countries over the last half century. See Figure 1 below.

- There has been a large increase in output per person (or standard of living).

- There has been a convergence of output per person across countries.

	Annual Growth Rate Output per Person (%)	Real Output per Person (2005 dollars)		
	1950–2009	1950	2009	2009/1950
France	2.5	7,112	30,821	4.3
Japan	3.9	3,118	31,958	10.2
United Kingdom	2.0	10,400	33,386	3.2
United States	1.9	13,183	41,102	3.1
Average	2.6	8,453	34,317	5.2

Notes: The data stop in 2009, the latest year (at this point) available in the Penn tables. The average in the last line is a simple unweighted average. *Source:* Alan Heston, Robert Summers, and Bettina Aten, Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011

Figure 1. The evolution of output per person in four rich countries since 1950

3 THINKING ABOUT GROWTH: A PRIMER

The aggregate production function. We use the framework developed originally by Robert Solow in the late 1950s. Assume that the **aggregate production function**—the relation between aggregate output and inputs in production—is given by

$$Y = F(K, N) \tag{3.1}$$

where Y is aggregate output, K is aggregate capital, and N is aggregate employment.[1] The above specification can be viewed as a generalization of the aggregate production function $Y = AN$ that we introduced earlier, which implies constant output per worker, thereby ruling out growth.

Returns to scale and returns to factors. There are three restrictions that we can reasonably impose on the aggregate production funtion:

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[1]The aggregate production function F also depends on the state of technology. The higher the state of technology, the higher $F(K, N)$ for given K and N.

- **Constant returns to scale**: if the scale of operation is doubled, i.e. the quantities of capital and labor are doubled, then output will also double. More generally, for any number x, we have

$$xY = F(xK, xN) \tag{3.2}$$

- **Decreasing returns to capital**: increases in capital lead to smaller and smaller increases in output.

- **Decreasing returns to labor**: increases in labor lead to smaller and smaller increases in output.

Output per worker and capital per worker. Under the assumption of constant returns to scale, if we set $x = 1/N$, then equation (3.2) becomes

$$\frac{Y}{N} = F\left(\frac{K}{N}, \frac{N}{N}\right) = F\left(\frac{K}{N}, 1\right) \tag{3.3}$$

where Y/N is output per worker and K/N is capital per worker. See Figure 2 below.
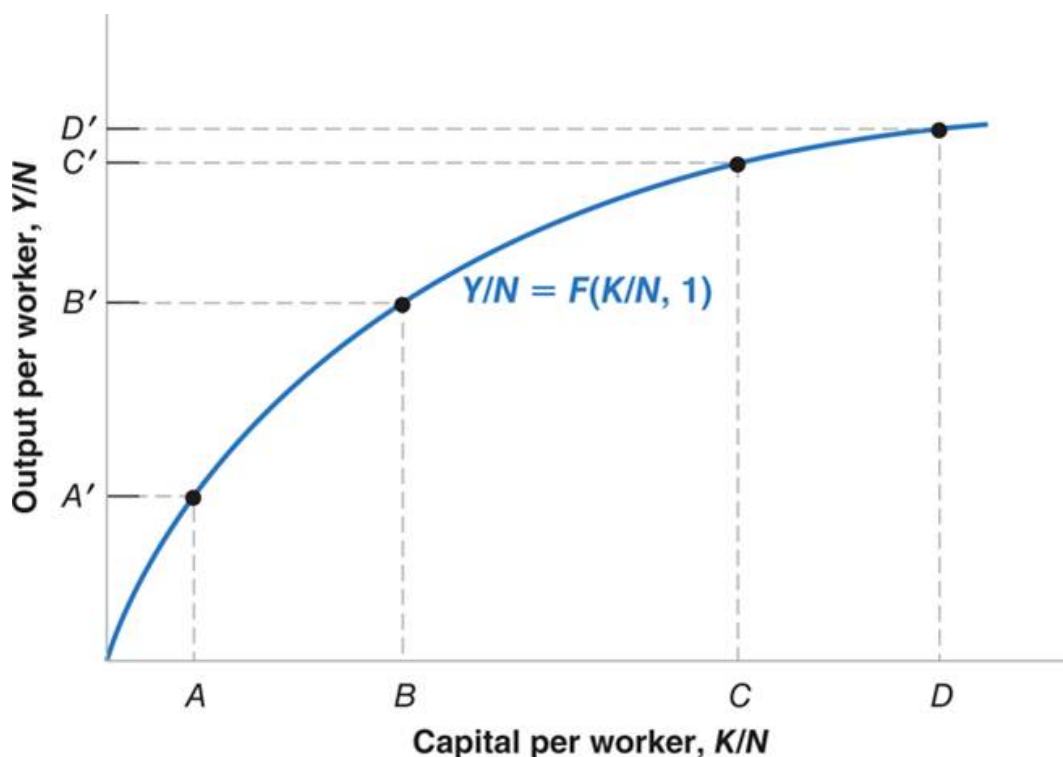

Figure 2. Output and capital per worker

The sources of growth. The above equation provides two sources of growth, i.e. increases in output per worker over time:

- **Capital accumulation**: increases in output per worker (Y/N) can come from increases in capital per worker (K/N). However, capital accumulation by itself cannot sustain growth due to decreasing returns to capital.

- **Technological progress**: increases in output per worker can also come from improvements in the state of technology that shift up the production function and lead to more output per worker given capital per worker. Sustained growth requires sustained technological progress. See Figure 3 below.
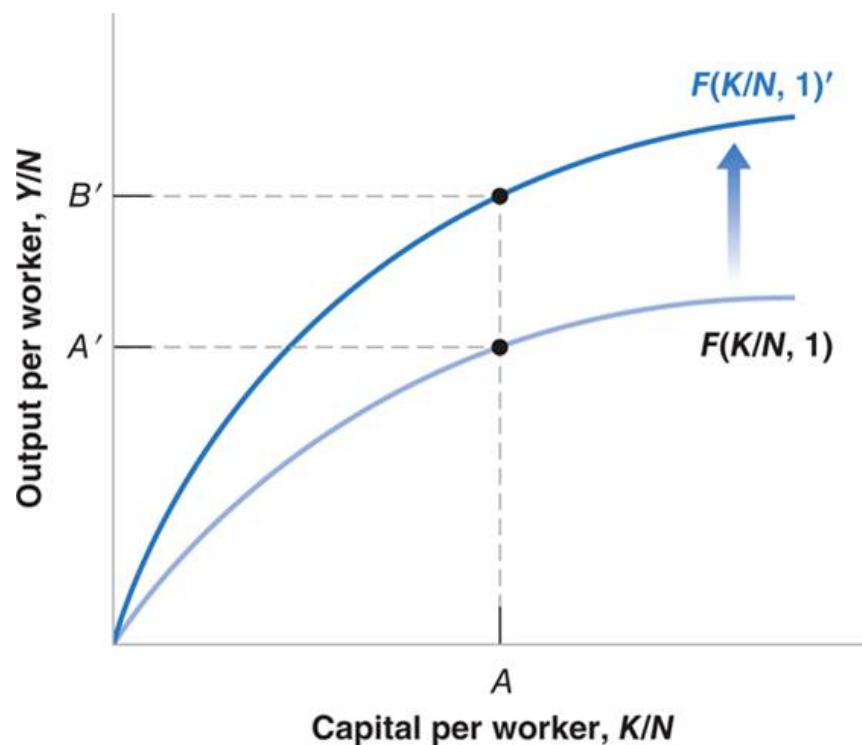
Figure 3. The effects of an improvement in the state of technology