Lecture # 2 -- Technology and Economic Growth

I. An Historical Perspective on Growth

- Note that even moderate economic growth is a recent phenomenon. (Note, figure shows GDP growth in the leading ("frontier") nation. Begins with UK data, switches to US in 1906, when US became the "frontier" nation.
    - Until 1700, UK grew at about 0.2% per year.
    - Growth reaches 1% per year around 1900
    - In US, growth was slow until after Great Depression and World War II.
- Similar trends occur in other countries
    - Consumption (and GDP) have risen remarkably fast in the modern era.
    - Note that the rate of improvement is higher for the later countries.
        - Japan grew 5.7% per year from 1958-1987
        - Why might this happen?
            - Follower countries can adopt innovations without doing the expensive R&D needed to create them, and can learn from the mistakes of leader countries.
            - Also, these countries can leapfrog over intermediate technologies.
    - This is a general trend. Average living levels have doubled or tripled in most of the world in the late 20th century (Table 3)
    - Technological innovation has played a key role in faster economic growth.
        - Before the Industrial Revolution, global output per capita grew at just 0.1%/year
        - Over the past 200 years, it has grown 1.2%/year.
- What about other measures?
    - GDP is the sum of the money values of all final goods and services produced in the domestic economy during a year.
        - Does not include sales of intermediate goods and services.
        - Only includes work done in the country.
        - Only market activity is included.
            - Since there isn't a market for environmental quality or health, such benefits are not included!!!
        - Moreover, technological change may be underestimated.
        - Critics note that GDP per capita does not always correlate with quality measures such as length of life or education.
    - Health issues
        - Life expectancy has also improved dramatically, with a similar pattern: a turning point can be identified after which life expectancy grew rapidly.
        - Improvements in life expectancy started later than for GDP in the early countries, but the advances spread more rapidly.
            - Once again, the magnitude of the growth was larger for the followers.

        - Diffusion is important. Followers can take advantage of advances already made in the leader countries.
- What precipitated periods of high growth?
    - Industrial Revolution #1 (1750-1830): steam engine and cotton gin
        - Railroads didn't have full effect in US until 1850-1900
        - However, Gordon notes life not pleasant in 1870.
            - E.g. no indoor plumbing, no window screens, horses used for local transportation (leads to manure in streets)
    - Industrial Revolution #2 (1870-1900): electricity, internal combustion engine, indoor plumbing
        - Motor power replaces animal power
        - No need to carry water inside
        - Travel and communications became quicker
            - Telephone, phonograph, and motion pictures all invented in 1880s
        - However, doesn't quickly lead to rapid growth in US.
        - US went from 75 percent rural to 80 percent urban
    - Industrial Revolution #3 (1960+): computers and Internet
        - Internet begins 1995, but fast computing began in 1960s
        - However, benefits don't appear in productivity statistics until 1990s
        - Moreover benefits go away by mid-2000s
    - Note the general nature of many of these technologies (e.g. *general purpose technologies*).
        - Takes time for their impact to diffuse throughout the economy

II. Is the Golden Age of Innovation Over?

- Gordon argues that nature of innovation has changed
    - Rather than replacing human labor, new IT improves communication and entertainment.
        - This has value, but not the same impact on productivity.
    - Consider Gordon's thought experiment:
        - Would you rather have all innovations up to 2002 only, but keep running water, or have all innovations until today (e.g. Facebook, smartphones) but give up running water and indoor toilets?

- What arguments does Gordon make to claim that growth will slow ("6 headwinds")?
    - Demographic dividend over
        - Women have entered the workforce & the baby-boomers are retiring
            - Consider growth equation from first class: if labor growth slows, so does economic growth
        - Relates to *Economist* article discussion of *extensive* vs. *intensive* growth
            - Extensive growth comes from adding labor or increasing education
                - Experience diminishing returns
            - In contrast, intensive growth improves productivity by coming up with better ways to do things (e.g. use resources more *intensively*)
    - Education attainment in US has leveled off
        - College is expensive
        - Students performing worse on national tests
    - Rising inequality
    - Interaction between globalization and ICT
        - Increases competition for US (e.g. easier to use inexpensive foreign labor)
        - Costs of offshoring are falling
        - Raises wages abroad, but hurts low income workers in the US
    - Challenge of energy and the environment
        - Productivity slowdown in 1970s began in most energy-intensive sectors
        - Moreover, regulations will be needed to address rising carbon emissions
    - Increasing household and government debt
        - Reduces disposable income
- Other arguments
    - R&D becoming less productive (diminishing returns)
    - As world becomes more complex, takes longer for scientists to learn what they need to know before they can discover new things

- Bailey *et al*. argue that growth need not slow
    - While IT may eliminate some jobs, it creates new opportunities
    - There are sectors of the economy that still lag behind
        - Health care
        - Education
        - Construction
    - See opportunities for new innovation
        - Manufacturing
            - Robotics/automation
            - 3D printing
        - Big data allows better management
        - Energy
            - Consider benefits of cheaper natural gas from fracking: lower energy costs and fewer carbon emissions
        - Health care
            - Better data could improve research
            - Personalized medicine
- Other arguments (from the *Economist* article)
    - Takes time for new innovations to have an impact. We might not yet have seen impact of IT in productivity statistics
        - Note lag that Gordon himself notes for impact of railroads in US
        - Electricity developed in 1880s, but didn't impact economy until 1920s

III. Convergence

- Note that growth and productivity is not falling everywhere.
    - Consider, for example, the data on growth rates presented in our first class.
- One possible explanation for different growth rates is convergence.
    - Traditional economic theory predicted that the growth rates of different countries would converge towards a "natural rate," which economists referred to as steady state growth.
    - Thus, developing countries would eventually be able to catch up with developed countries.
- Theoretical reasons for convergence:
    - Diminishing returns: Marginal returns to capital investment lower in countries with high ratios of capital to labor.
        - Investments in physical capital are a major source of growth in standard economic models.
        - As the capital stock of a country grows, they will be unable to sustain the same level of returns.
    - The cost of advancing technology rises as the level of technology rises.
    - Lagging countries can take advantage of the growth of developing countries:
        - Can benefit from technology spillovers
        - Can avoid the mistakes of the leading economies
        - Late adopters of a technology are freer to develop institutions consistent with the technology.
- Baumol (1986) presented evidence of convergence.
    - Baumol (1986) noted wide gaps in per capita income and labor productivity among developed countries (fig. 2.2 a & b).
        - These gaps seemed larger in the 20th century than the 19th century.
    - He also notes that the countries with the lowest GDP/work hour in 1870 grew more rapidly.
        - Big winners: Japan, & Italy.
- Evidence to the contrary
    - Criticisms of Baumol: by only "picking winners" he couldn't help but find convergence.
        - DeLong (1988) did a similar exercise, but looked at all rich countries in 1877.
            - He looked at 22 "once rich countries" and found little evidence of convergence.
            - Countries where convergence fails: Spain, Portugal, Ireland, Chile, and Argentina.
        - Why didn't these countries grow?
            - DeLong finds religion and/or democracy to be important.
            - Note that recent work has found that equatorial climates do not grow as fast.

- Conditional convergence
    - Of course, the rate of growth depends on more than the starting value.
    - Variables such as savings rates, investment, population growth, education, politics, and culture should also matter.
        - Latin American countries haven't experienced the same productivity growth as East Asia.
            - Firms are smaller
                - Often operate in the informal economy due to costly regulations
            - 60% of Latin Americans work in service firms
                - This sector experiences less productivity growth.
    - Evidence suggests developed countries have avoided convergence by:
        - increasing capital investment
        - investing in education
        - slowing population growth

IV. Growth Economics

- Neoclassical growth
    - Motivated by skepticism that a sustained rise in the savings rate could lead to faster economic growth, and by Solow's work on the "Solow residual" in the 1950s.
    - Technological change replaced investment (growth of K) as the primary engine of growth.
    - The neoclassical model predicted that increased investment could lead to a spurt of growth, but that growth rates would return to the earlier "natural" level.
        - Investment leads to increases in the capital stock.
        - Over time the capital-labor ratio will rise.
            - As a result, the marginal product of capital will fall.
        - Steady state growth will result.
    - This model provides the theoretical foundation for predictions of convergence.
        - Neoclassical theorists did realize that growth could be sustained if technology progressed enough to maintain the productivity of labor.
        - However, neoclassical models treated technology as exogenous.
- Endogenous growth
    - Motivation:
        1. The growth rate of the world's technological leader, the US, has been rising over time.
            - In the neoclassical model, this can only happen if exogenous technological change steadily increases.
        2. Countries do not appear to be converging, as predicted by the neoclassical model.
    - In endogenous growth models, long-run growth is driven by the accumulation of knowledge.

        - Thus, technology is endogenous, rather than exogenous (taken as given).
        - Profit-maximizing firms respond to incentives regarding innovation.
    - How can R&D, which is just 2% of GDP, make such a difference?
        - Knowledge is cumulative, whereas physical capital (machines) must be replaced
        - Social rates of return on R&D are high
    - Modeling endogenous growth
        - Unlike neoclassical models, we cannot assume that firms simply act as price takers in perfect competition.
            - If they did, there would be no incentive to innovate.
        - Rather, innovation leads to monopoly power and positive profits.
        - Many studies note that human capital plays a role in growth. Often, this is interpreted as effort devoted to schooling and training.
            - Human capital can be modeled as augmenting the labor force. That is, the quality of labor increases.
    - Although knowledge production experiences diminishing returns at the firm level, positive externalities lead to increasing returns for the economy as a whole.
    - Implication:
        - Because of externalities, the market equilibrium is not optimal.
    - Important lessons:
        - The most important contribution of these models for economic development is noting that human capital is endogenous.
            - Thus, there need not be diminishing marginal returns to investment.
            - If human capital keeps up with other investment, returns can be sustained.
                - Explains why countries like Japan, Italy, Korea, and Taiwan were successful when others were not.
        - Dynamic comparative advantage
            - Countries may have comparative advantage in high or low technology sectors.
            - If knowledge flows freely, trade patterns can transfer technology.
            - However, Grossman and Helpman note that knowledge externalities are often local or national in nature (e.g. Silicon Valley, Route 128).
                - This suggests that the advantage of a leader country can persist over time.
        - Integration and growth
            - Why might integration into world markets speed growth?
                - Access to a larger technical knowledge base.
                - International competition can mitigate redundancy in R&D.

        - Firms will need to generate products new to the global market, not just the national market.
    - Expands the size of the consumer base.
        - Counteracting force: competition may lower the returns to R&D if firms cannot hold their own.
- When can closing off trade help?
    - A country with a relative abundance of natural resources and unskilled labor may end up trading those resources at the expense of developing human capital.
    - If technological spillovers are national in scope, researchers in a country with a small knowledge base may find it difficult to compete with foreign researchers.
        - Long run growth may be faster if the country waits to “catch up” before trading.