Beyond Physical Capital

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June 2025

Recap: Solow

- In the Solow model, output was driven by capital and labor $Y = AK^{\alpha}L^{1-\alpha}$.
- Capital deepening (increasing $k \equiv K/L$) increased output per worker with diminishing returns.
- Due to depreciation and diminishing returns, the economy converged to a steady state. Long-run per-capita growth could only come from *exogenous* technical progress (increases in TFP (A)), not just piling up more machines.
- Differences in investment explained some income differences, but capital alone couldn't plausibly account for huge gaps.

Recap: Romer

- In the Romer model, long-term growth was driven by increases in the stock of ideas $Y = A^{\gamma}K^{\alpha}L^{1-\alpha}$ where the stock of ideas (A) grew from R&D.
- Ideas were non-rivalrous, one person's use of knowledge did not prevent others from using it as well.
- Unlike physical capital, knowledge fueled long-run growth in output per person since new ideas continually raised productivity.
- Technological innovation drove growth, while capital amplified growth.
- This leads us to ask what intangible factors (innovation, human skills), drive growth in the stock of ideas?

Limitations of Physical Capital

- Physical capital alone has a declining marginal product. The addition of each new machine yields smaller gains in output per worker holding workers constant.
- Physical capital differences (investment rate ($\bar{s}Y_t$) in the Solow model) explained some cross-country differences, but not the gaps we observed.
- There could be important productive assets left out of the traditional measure of physical capital.

Capital Measurement

- Physical capital is typically measured via the Perpetual Inventory Method.
- The capital accumulation equation is

$$K_{t+1} = I_t + (1 - \delta)K_t$$

  where δ is depreciation and I_t is new investment
- The Perpetual Inventory Method involves choosing a base year estimate (K_0), calculating investment for each year I_t for $t = 0, 1, 2, ...$, calculating a depreciation rate δ, and applying the accumulation equation recursively.

Measurement Challenges

- Different types and qualities of equipment could have different depreciation rates (δ). Perhaps technological changes can drive capital quality improvements over time.
- Data quality on investment levels (I_t for $t = 1, 2, ...$) can be poor in different countries.
- We still need to estimate initial capital levels K_0.
- Errors in initial capital levels, the depreciation rate, or initial sequences of investment can have large impacts on the sequence of capital.
- Nonetheless, the Perpetual Inventory Method provides useful, workable estimates of the quantity of physical capital over time.

What Counts as Capital?

- Our definition of capital counts includes tangible, fixed assets (machines, warehouses, etc.).
- This definition omits intangible investments that could conceivably contribute to output (developing new software, building a client network, etc.).
- If a country heavily invests in intangibles, it might seem as if the country has a low capital stock using conventional measures, even though these intangible investments could be helping the country grow.
- Recently, there has been a concerted effort to better measure these assets. Widely used datasets such as NIPA (National Income and Product Accounts) recently began including R&D.[1]

[1] See David and Gourio, "The Rise of Intangible Investment and the Transmission of Monetary Policy" (2023)

Broadening our View

- Physical capital is essential but not sufficient to explain differences in growth rates across countries. Below are motivations for two categories we will consider.
- **Human factors:** Workers are not all the same. They can differ in things such as skills, education, and health, which drives how effectively they use physical capital.
- **Unmeasured factors:** Business owners and innovators put in effort to build up reserved of things that do not have immediate returns such as client relationships and organizational know-how.

Human Capital

- Human capital is the stock of knowledge, skills, and experiences that makes individuals productive.
- Similar to how physical investment today paid off by increasing production down the road in the Solow model, investment in human capital today pays off through increased productivity in the future.
- Human capital is largely acquired. Schooling, on-the-job training, and life experience all contribute towards the accumulation of human capital.
- Human capital can be broadened to also include health, nutrition, and other skills.

Human Capital: History

- As far back as Adam Smith, economists have noted that worker abilities have economic value. However labor was treated as a raw input and improvements in labor quality not formally modeled.
- **Theory**: In the 1950's-1960's, economists Theodore Schultz and Gary Becker wrote foundational work in human capital theory. They argued expenditures on education and training should be viewed as investments in capital. Becker's 1964 book "Human Capital" formalized these ideas and spurred decades of research.
- **Empirical Work:** Economists such as Jacob Mincer showed strong links between schooling and earnings.
- In the 1980's and 1990's macroeconomists began incorporating human capital explicitly in models.

Human Capital: Studying Growth

- Robert Lucas (1988)[2] introduced a model where human capital accumulation drove long-run growth in which increasing stock human capital increased productivity. This model could sustain growth and helped explain by some countries grow faster if they invest more in education.
- Augmented Solow Model: Mankiw, Romer, and Weil (1992)[3] incorporated human capital as a factor in the Solow model. The augmented Solow model improved the model fit to cross-country data, as countries with higher education had higher steady-state incomes, narrowing the TFP gap we discussed.
- Human capital within an individual has diminishing returns, an extra year of schooling helps but the incremental benefits declines with additional years of schooling.
- However, from Lucas' work, if educated workers create new ideas or help others learn, the social return on human capital can exceed the private return.

[2] See Robert E. Lucas Jr., "On the mechanics of economic development", JME, (1993)

[3] See Mankiw, Romer, and Weil, "A Contribution to the Empirics of Economic Growth", QJE, (1992)

Education and Investment

- Schooling quantity is a comparatively measurable investment in human capital.
- From primary through secondary education, individuals and societies (via taxes and public funding), spend time and money to increase knowledge with the expectation that a more educated workforce can both use existing technology more efficiently and innovate new technologies faster.
- While years of schooling is very easy to measure, education can also differ by quality.
- Two individuals can have the same level of education, but if one had better teachers and curricula, then they could end with different levels of human capital. Skill assessments (SAT, ACT, literacy tests) can reveal large differences for the same quantity of schooling when holding other factors constant.

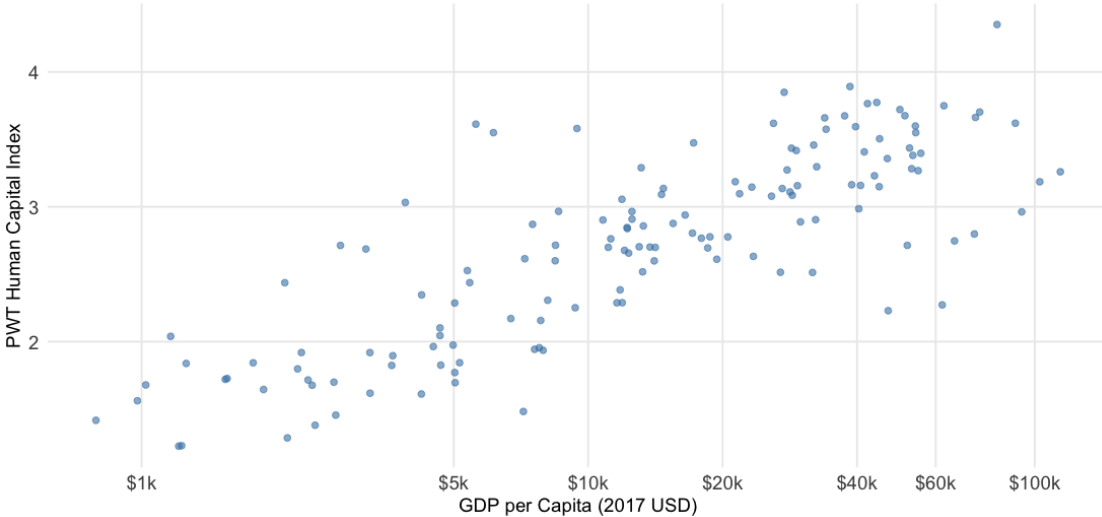
Education and Investment

- Learning doesn't end with schooling, firms and workers invest in training programs which can be both sector and company specific.
- In a changing economy, workers can acquire new certifications, teach themselves new skills, or return to get more education.
- Governments often offer retraining programs for workers in sectors affected by creative destruction or trade shocks.

Education Choices

- Consider an individual choosing whether or not to attend college.
- In a country without many jobs that require a college education, the return to attending college would be low.
- In a developing country with low incomes, the opportunity costs of not working, along with the savings required for tuition would prevent many from being able to attend.
- We'd expect human capital to be very related to a country's economic status.

Education and GDP per Capita[4]



[4]Penn World Tables v.10.01

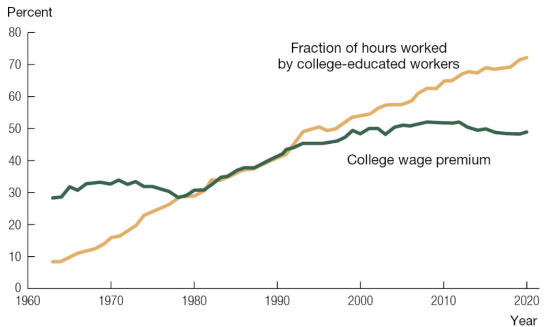
Returns to Education

- Let's return to the education decision, this time in the U.S.
- College tuition has risen rapidly over the past few decades.
- The benefits of college education include higher wages from employers after education.
- For college to still be worth the pursuit, the return to college should have increased over the past as well.

College Wage Premium

FIGURE 7.8

College versus High School Wages and Employment



Source: Daron Acemoglu and Carlos Molina, private communication, April 2, 2023. The college wage premium is computed after controlling for various demographic characteristics such as region, age, race, gender, and experience.

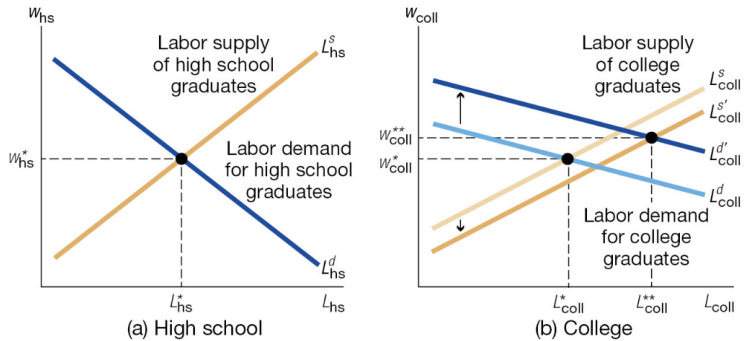
Rising Return to Education

- We see that the college premium has increased over time.
- We also see that the share of hours worked from college-educated workers has increased dramatically over time.
- Over the preceding decades, the U.S. workforce has increasingly become more educated while the return to this education has increased as well.

Rising Returns to Education

FIGURE 7.9

Understanding the Rising Return to Education



Explaining Trends: I

- What changes in the economy have led to the large increase in demand for highly educated workers?
- A reason often suggested by economists is skill-biased technical change.
- This reasoning says that technological progress over the past several decades (cheapening of computational power, more advanced software, etc.) have disproportionately increased the productivity of highly skilled workers.
- Recently, some economists have suggested that increases in technological productivity may increasingly be used as a substitute for highly skilled labor in the coming future.

Explaining Trends: II

- Another explanation for the rise in the relative wage is globalization.
- Before globalization, the size of the educated workforce in the U.S. ensured lower wages.
- Compared to global averages, the U.S. workforce is highly educated.
- This argument claims that opening up to a world in which highly educated workers are scarce caused wages to rise.

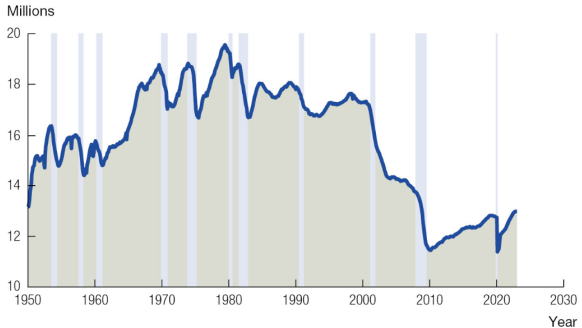
Explaining Trends

- Globalization has also exposed lower-skilled workers in the U.S. to much larger supply of lower-skilled workers.
- Based off our discussion, we'd expect to see declines in employment in areas that both don't require college education and can be done elsewhere in the world.

U.S. Employment: Manufacturing

FIGURE 7.10

U.S. Employment in Manufacturing



Source: U.S. Bureau of Labor Statistics, retrieved from FRED, Federal Reserve Bank of St. Louis; fred.stlouisfed.org/series/manemp.

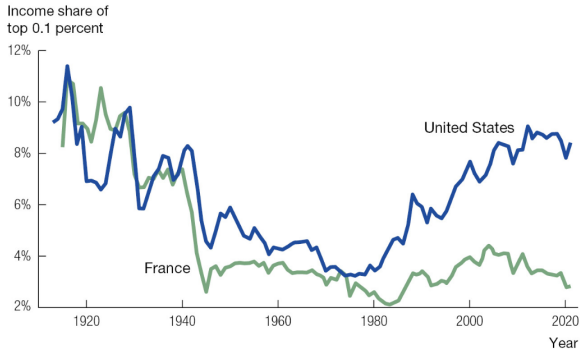
Returns to Education and Inequality

- We saw that the college wage premium has grown, along with the share of hours worked by college-educated workers.
- Many of these workers are employed in sectors centered on idea production and intellectual property, rather than the production of goods.
- As we saw in the last lecture, these sectors often exhibit increasing returns to scale and do not exhibit perfectly competitive markets.
- We might expect that as such firms become more central to the economy, incomes become more concentrated, contributing to a rise in inequality.

Case Study: Income Inequality

FIGURE 7.11

Income Inequality in the United States and France



Source: Thomas Piketty and Emmanuel Saez, "Income Inequality in the United States, 1913–1998," *Quarterly Journal of Economics*, vol. 118, no. 1 (February 2003), pp. 1–39. Updated data wid.world.

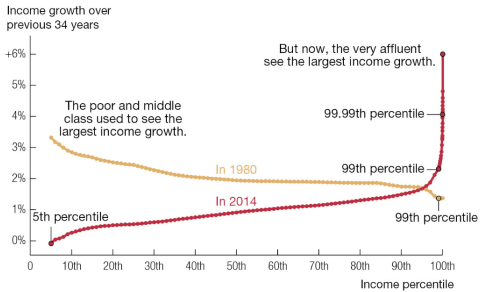
Economic Growth: An Aside

- So far, we have discussed economic growth in terms of average income per person.
- We have made no statements or measurements on how economic growth has been distributed across people.
- As you will see later in the course, government programs play an important role in determining the total income of poorer households.
- After accounting for taxes, transfers, and non-cash benefits, we can consider changes in the income growth rate over each percentile of the population.

Economic Growth

FIGURE 7.12

Economic Growth by Income Percentile



Source: This figure is based on data from Thomas Piketty, Emmanuel Saez, and Gabriel Zucman, "Distributional National Accounts: Methods and Estimates for the United States," *Quarterly Journal of Economics*, vol. 133 (2018), pp. 553–609. David Leonhardt in "Our Broken Economy, in One Simple Chart," *New York Times*, August 7, 2017, worked with the original authors to create this version that includes the 1980 line.

Health as human capital

- We've discussed how workers and work-forces differed in education levels.
- Another dimension economists often consider is health.
- Healthy individuals have higher energy, can work longer hours, are less likely to miss work from illness, and can retire later.
- Health in early life can also impact cognitive abilities and learning capacity.
- Expected life expectancies can impact education decisions (if you expect to live longer the payoff for additional schooling increases)

Unmeasured capital

- Last lecture we gave the example of a company spending $2.5 billion on R&D to develop a new drug. The company invested to discover a new drug.
- Intangible investment such as R&D is plays a key part in the growth and development of countries over time.
- Investing heavily in R&D, software, and other knowledge-generating activities leads to increases in productivity.

Unmeasured capital

- Advanced economies tend to have higher intangible capital (more things such as research labs, computation infrastructure, patented technologies) which contribute to higher productivity.
- The accumulation of intangible capital benefits from supportive institutions such as universities, R&D tax credits, intellectual property rights, venture capital, etc.
- Intangible capital is a complement to human capital. A more educated workforce is better at producing and implementing new ideas.

Unmeasured capital: An example

- Imagine an entrepreneur who starts an arts store and has just enough money for a website.
- Suppose the entrepreneur works 16 hour days doing everything from designing products, to shaping the website, to handling customer service, to marketing through social media.
- The entrepreneur does this for three years, drawing just enough salary to cover rent and food.
- Suppose in a few years the store has a reputable brand name, great reviews online, a streamlined production process, and propriety designs. Note that none of this value came from the injection of financial capital.

Unmeasured capital: An example

- If the entrepreneur sold the store, the business could well be worth more than the sum of the parts.
- The entrepreneur converted their labor into business equity, this is an example of what economists call sweat equity.
- This scenario is common for startups and businesses.
- Founders and small owners often don't pay themselves market wages in early years and the foregone wages and extra hours are effectively an equity contribution.
- When the risk pays off, sweat equity can yield very large returns.

Measurement Challenges

- Sweat equity, along with other forms of unmeasured capital, is not captured directly in official statistics.
- National accounts consider the income people do receive. If an owner doesn't take a salary, their labor is not considered.
- This is a problem typical of unmeasured capital, which often takes more creative ways of measurement than other forms of capital.

Measurement Challenges: An example

- Even though these alternative forms of capital can be difficult to measure, their impact and role in the economy are quite substantial.
- Bhandari and McGrattan (2020)[5] estimate that for the U.S. private business sector, the value of sweat equity is about 1.2 times GDP, roughly on par with the value of all fixed tangible assets in those businesses.
- While this study focused on the U.S., one can imagine the importance of sweat equity in environments with many micro-enterprises and a lack of access to financial capital, where the owners' labor input might be the dominant route to growth.

[5] See Anmol Bhandari and Ellen McGrattan, "Sweat Equity in U.S. Private Business", QJE, (2020)

Importance

- We just saw an example of how unmeasured capital can have huge magnitudes.
- What are the impacts of not considering unmeasured capital?
- Consider a policymaker debating a change in tax policy.
- Neglecting unmeasured capital (such as sweat equity) might lead us to underestimate the benefit of a reduction in the tax rate on private businesses.
- Sweat equity is impacted greatly by incentives for entrepreneurs, meaning benefits for programs to incentivize entrepreneurship will be undervalued when not considering this form of capital.
- Neglecting sweat equity might lead banks to under-lend to credible firms.

Remaining gaps

- Even under expanded definitions of human capital, large residual differences in TFP remain.
- Economists often point to technology adoption, quality of institutions, and other barriers as factors that drive these gaps.
- Example: Suppose a country blocks competition to protect a favored industry, firms in this industry might under-invest in production and use outdated technologies to produce.

Remaining gaps

- In the book "Barriers to Riches", economists Edward Prescott and Stephen Parente argue that poorer countries tend to have barriers to both competition and technology adoption.
- Example of these barriers include legal barriers to new firm entry, restrictions on imports of better machines, or laws that ensure industries are dominated by favored groups.
- These barriers prevent production by the best firms using the best methods.
- While in this lecture we discussed different forms of capital, we must also consider the environment in which the capital is used.

Summary

- If we broaden investment to be any payments that give returns in the future, we can expand the role of capital to include things such as
  - Education
  - Health
  - R&D expenditures
  - Sweat equity
- While the definition of capital has begun to grow in recent years to include things such as R&D, these measures differ in quality across countries.
- Adding these alternative forms of capital gives us a fuller picture.

Moving Forward

- Include human capital in the Solow model.
- Compare the accuracy of human capital in the Solow model with that of our previous work.
- Do the same for unmeasured capital.