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The Futurity of US Economic Process Growth

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Abstract:

Arguably the most crucial fact of the last century is the firm rise in standards of life throughout much of the world. Will this rise extend? We discuss what advanced growth theory has to say about economic process in the United States over the next 25 to 50 years. Encouraged growth theory suggests that more than 3/4 of growth since 1950 contemplates rising educational attainment and research saturation. As these transitions dynamic fade, U.S. economic growth is likely to slow at some point. However, the rise of China, India, and other coming forth savings may allow another few decades of rapid growth in world investigators. Finally, and more speculatively, the shape of the idea production function brings in a fundamental doubt into the future of growth. For example, the possibility that AI will allow machines to substitute workers to some extent could lead to higher growth in the future.

Keywords: standards decades' production etc

I. INTRODUCTION

Arguably the most substantial fact of the last hundred is the steady rise in living standard during much of the world. Will this rise cover? We talk about what modern development possibility has to say about physical process in the America over the next 25 to 50 years.

II. THE FACTS

Figure 1 demonstrates GDP per person for the United States among 1870 and the present. The constancy of the rate of growth is singular and storming, with GDP per person lying close to a linear time trend with a slope of just under 2 percent per year. Even the Depression was a persistent but not permanent deviation. A inviting conclusion from this figure is that a good guess for future growth is around 2 percent per year.

Despite the telling fit of a linear trend, growth has at times deviated noticeably from a 2-percent baseline. Visually, for example, it is clear that growth was slower pre-1929 than post-1950. Between 1870 and 2007 (to exclude the Great Recession), growth was 2.03 percent per year. Before 1929, development was a quarter point slower (1.76), while since then it has been a quarter point faster (2.23).1 Development from 1950 to 1973 was faster still (2.50), but then slowed markedly until 1995 (1.82). The U.S. experience may also understate uncertainty about the future, since other nations have often seen level as well as growth rate changes. Early in the 20th century, for example, the U.K. was substantially richer than the United States; by 1929, the position was reversed. Japan's experience since 1990 — and the financial crisis and Great Recession more recently — arouse a related concern. Standard growth theory implies that a financial crisis should not have a long-term effect on income per person: if the rate of time preference and the other parameters of the economic natural world are unchanged, the economy should finally return to its original steady state. This penetration is strongly affirmed by the U.S. experience following the Great Depression, as shown in Figure 1. Despite the large damaging shocks of 1929 and the 1930s, the Great Depression was, in the end, temporary — the economy returned to its balanced growth path. However, this logic has failed dramatically in the case of Japan after 1990. Japanese GDP per capita indisposed at 86% of the U.S. level in 1995 and has since fallen to 75%. This observation, which is not easy to understand in terms of the theory we lay out next, is an important cautionary reminder about development expulsions.

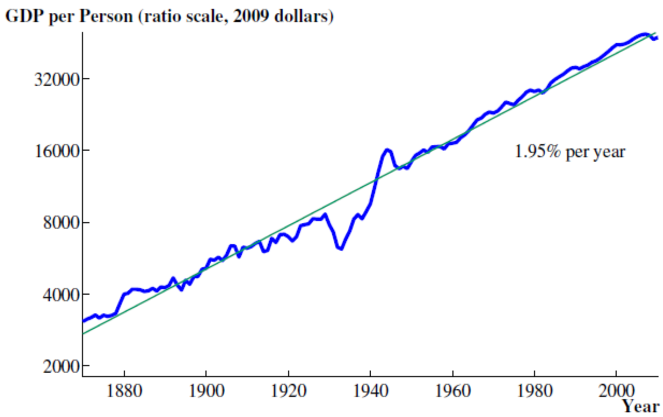


Figure 1: U.S. GDP per Person

Information for 1870 to 1929 is from Maddison (2008). Data for 1929 to 2012 are from the Bureau of Economic Psychoanalysis.

III. DESCRIBING WITH ADVANCED GROWTH THEORY

We now turn to an interpreting of growth accounting proposed by the semi-androgenic growth model of Jones (2002), in which long-run development arises from the discovery of new ideas. Final output depends on physical capital K, hours worked N, human capital per person h, and the stock of ideas A: $Y = K^{\alpha}(AhN)^{1-\alpha}$. Traditional growth accounting, following Solow (1957), calculates A as a residual. Modern growth theory explains that residual in terms of economical forces.

Embedded in this product function is the key insight of Romer (1990): the nonscientific of ideas leads to increasing brings back. As a result, income per person depends upon the total number of ideas, not on ideas per person. This contrasts sharply with capital or other rival inputs. Adding one new tractor to the economy benefits one farmer. Adding one new idea potentially gains everyone, regardless of the size of the economy, because the idea is not consumed with use.

New ideas come froman idea production function that depends on the number of individuals looking for new ideas as well as on the existing stock of ideas:

$$\dot{A} = Rf(A) = \beta R A^{\phi} \qquad (1)$$

Where R is the number of investigators and ˙A is the flow of new ideas produced over time. In the long run, the stock of ideas is relative to the number of researchers, which in turn is proportional to population. Thus, scale (e.g., the population of countries producing new ideas) matters for idea-based thriftinesses.

Accepting rates of growth are constant—a reasonable approximation for the U.S. economy — Figure 2 resumes the resulting growth explaining the period 1950–2007.2 Importantly, this is not necessarily (and, we argue below, is not) the balanced-growth path.

Output per person, y, depends upon four terms. First is the capital-output ratio, as in Solow (1956). Second is human capital per person, as in Denison (1962) and Lucas (1988). Third is research chroma, the investment rate that applies to the hunt for new ideas (here, researchers as a share of all workers), as underlined by Romer (1990), Aghion and Howitt (1992), and Gross estate and Help man (1991). Fourth part is the number of individuals in the economy, as in the semi-endogenous growth examples of Jones (1995), Kortum (1997), and Segerstrom (1998). The last two prices, which correspond to TFP, constitute the stock of ideas. That stock is inferred from the "flow" of investment funds (research intensity and population).

$$y^* \approx \left(\frac{K}{Y}\right)^{\beta} \cdot h \cdot (\text{R\&D intensity})^{\gamma} \cdot L^{\gamma}$$

	Solow	Lucas	Romer/AH/GH	J/K/S
2.0	0.0	0.4	1.2	0.4
(100%)	(0%)	(20%)	(58%)	(21%)

Figure 2: Growth Describing with Modern Growth Theory

As the compute shows, the 2 share annual growth in labor productiveness largely came from rising human capital (0.4 p.p. per year, about 20 percent of the total) and rising research intensity in the advanced countries of the world (1.2 p.p., or 58 percent of the total).

The contribution of human capital is easy to understand. The educational attainment of adults has been rising about one year per decade. AMincerian return to education of 6 percent would then imply about 0.6 percentage points extra growth each year. In the accounting above, we use an index of labor quality from Jorgenson, Ho and Samuels (2013), which grows a bitmore slowly. They estimate the educational contribution somewhat differently and include additional aspects of labor quality, such as demographics. But rising education is still the key driver in their index.

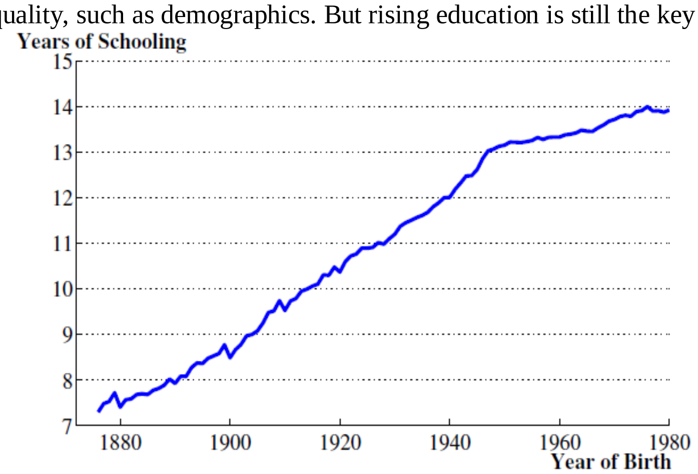


Figure 3: Educational Attainment by Birth Cohort

Figure 3 demonstrates data on informative attainment by birth cohort rather than for the cross-section of actors. After 1950, the rise in education slows markedly and has ceased for the most recent age bracket. Nothing in the model requires this — educational attainment could rise with life expectancy and could even rise faster than life expectancy for a long time. However, educational attainment in the data does slow. In the future, one can reasonably expect a reduced donation from education and, other things equal, slower income growth.

Inch sum, the account statement implies that growth over the past 50 years largely reflected transient factors. The rise in educational attainment is already slowing, and the fraction of the labor force engaged in research cannot growth forever. Taken literally, only the scale-effects term—equal to 0.4 pp, or 21 percent of growth—generates sustainable long-run growth. Even this term could itself be slowing as fertility rates decline. We do not know *when* this long run will occur, but Figure 2 implies that future growth might be significantly lower than over the past half century.

IV. DECREASING BRINGS BACK, ROBOTS, AND CHINA

Will growth, in fact, slow sharply in the coming decades? The depicting above depends on assumptions about the shape of the idea product function and the growth of inputs into explore.

Specifically, recall that fundamental the parameter in Figure 2 is the yield function for new ideas in equation

$$\dot{A} = Rf(A) = \beta RA^{\phi}.$$

Restricting f (A) to be a power function is required for balanced growth but still allows flexibility.

For example, the estimate of $\gamma = 1/(1-\phi)$ in Figure 2 implies that, historically, _ < 0. That is, as more ideas are discovered, it can become harder and harder to discover the next new idea—a "fishing out" argument. Similarly, Cowen (2011) and Gordon (2012) argue that we may have "cherry picked" the most easily-discovered and important ideas already, perhaps implying slower growth in the future.4 Note that diminishing returns to the idea production function in equation (1) is consistent with balanced growth even if _ is negative. Though elides are harder to find, balanced growth can still occur because of exponential growth in the number of researchers, R. The difficulty of making proportional increments is offset by growing efforts to push the frontier forward.

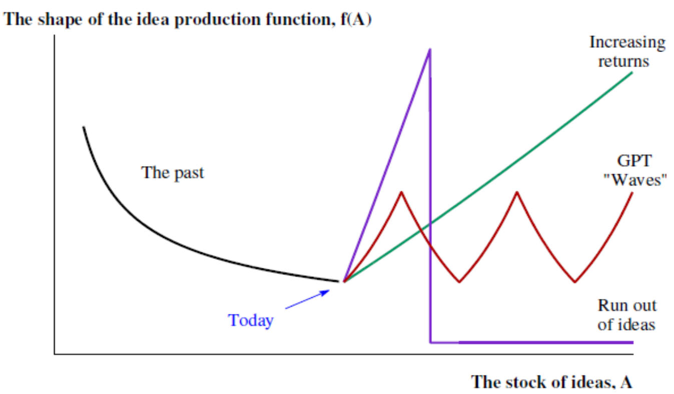
Of course, while bounding f(A) to be a power-function is commodious and tractable, it might not be realistic. Moreover, the shape of f(A) we have seen in the pastmight not be a reliable guide to the shape of f(A) at higher (future) levels of A. For example, consider the alternative paths shown in Figure 4. Here, the idea production function of the past exhibits diminishing returns—it gets more difficult and harder to discover new ideas. This path might continue into the future. Alternatively, we could reach an inflection point, after which it becomes easier and easier to discover new ideas. Or this could be true for awhile, but then maybe there are no additional new ideas to discover and f(A) drops to zero. Or perhaps there are beckons of good and bad periods comparable to "general purpose technologies." Each option implies very different paths for future economic growth.

A second crucial considerateness is growth in research inputs, R. In the accounting above, R has been growing faster than population. This cannot continue forever, pointing towards slower future growth. But the number of relevant researchers might grow for a long time, and new research engineering's might allow computers and robots to replace labor.

In terms of the number of investigators, developing economies are becoming richer and increasingly contribute to pushing the technological frontier forward. Figure 5 shows that South Korea and China exhibit particularly rapid growth in research spending—faster than even their already rapidGDP growth rates. China and India together have more than 1/3 of the world's population, so these economies could contribute considerably to future technological progress, far beyond what has probably been a negligible contribution over the last 50 years. Freeman (2009) points out that in 1978, China produced almost no Ph.D.'s in science and engineering, but by 2010, they were producing 25 percent *more* than the United States. How many future Thomas Edisons and Steve Jobses are there in China and India, waiting to realize their potential?

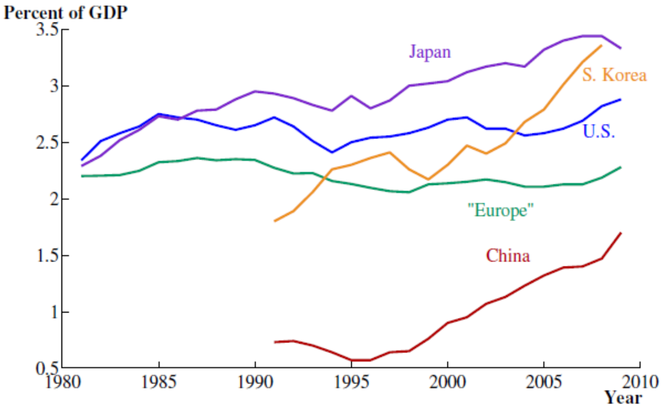
Even more speculatively, AI and machine learning could allow data processor and robots to increasingly replace labor in the production function for goods. Brynjolfsson and McAfee (2012) discuss this possibility. In standard growth models, it is quite easy to show that this can lead to a rising capital share — which we intriguingly already see in many countries since around 1980 (Karabarbounis and Neiman, 2013) — and to rising growth rates. In the limit, if capital can replace labor entirely, growth rates could explode, with incomes becoming infinite in finite time.

Figure 4: Alternative Futures?



The shape of the idea production function for future levels of Anteed not look like it has in the past.

Figure 5: R&D Expenditures as a share of GDP



Source: *NSF Science and Engineering Inicators, 2012,* Appendix Table 04-43. “Europe” is the unweighted average of the numbers for France, Germany, and the United Kingdom.

V. CONCLUSION

Several recent papers project future growth using a neoclassical growth model. Byrne, Oliner and Sichel (2013), for example, analyze recent trends in semiconductors to obtain insight into the current shape of the idea production function and undertake projections. But modern growth theory suggests that such projections are at best a local approximation. The roughly constant growth of the past century and a half does notmean the U.S. is on a steady-state path, and the past—even the recent past—could be a poor guide to the future. Our analysis suggests several key considerations. First, growth in educational attainment, developed-economy R&D intensity, and population are all likely to be slower in the future than in the past. These factors point to slower growth in U.S. living standards. Second, a counterbalancing factor is the rise of China, India, and other emerging economies, which likely implies rapid growth in world researchers for at least the next several decades. Third, andmore speculatively, the shape of the idea production function introduces a fundamental uncertainty into the future of growth. For example, the possibility that artificial intelligence will allow machines to replace workers to some extent could lead to higher growth in the future. Finally, other considerations we have not had space to address could impact future growth, including the rise in income inequality, climate change, and the systematic shift of the economy toward health care.

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