The Past and Future of Innovation: Can Progress be sustained?

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Is Growth Sustainable?

The curse of concavity, a.k.a. diminishing returns. Obvious in capital accumulation.

Also holds for:

- Smithian Growth (gains from trade)
- Northian Growth (gains from better resource allocations due to institutional change).

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Does it also hold for technological progress, which has increasingly assumed center stage in the economic growth story since 1750?

This is more controversial:

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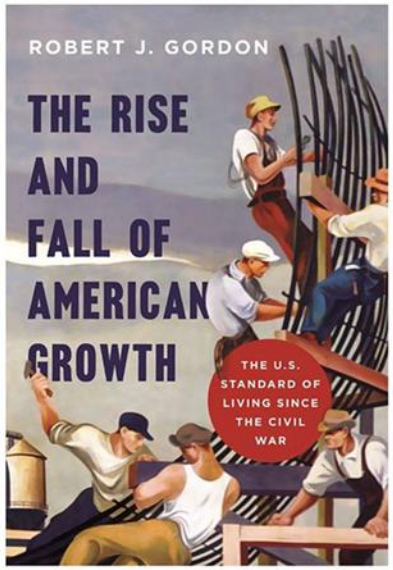
Have the low-hanging fruits all been picked?

The technopessimist interpretation (for instance Robert Gordon) says that the low-hanging fruits of invention have mostly been picked.



Future inventions, we are told, will not have nearly as radical an effect as before. And they will cost more. Growth will run into “headwinds” (e.g., fiscal and demographic problems and slow down).

Some research surely points in this direction

American Economic Review 2020, 110(4): 1104–1144
https://doi.org/10.1257/aer.20180338

Are Ideas Getting Harder to Find?†

By NICHOLAS BLOOM, CHARLES I. JONES, JOHN VAN REENEN, AND MICHAEL WEBB*

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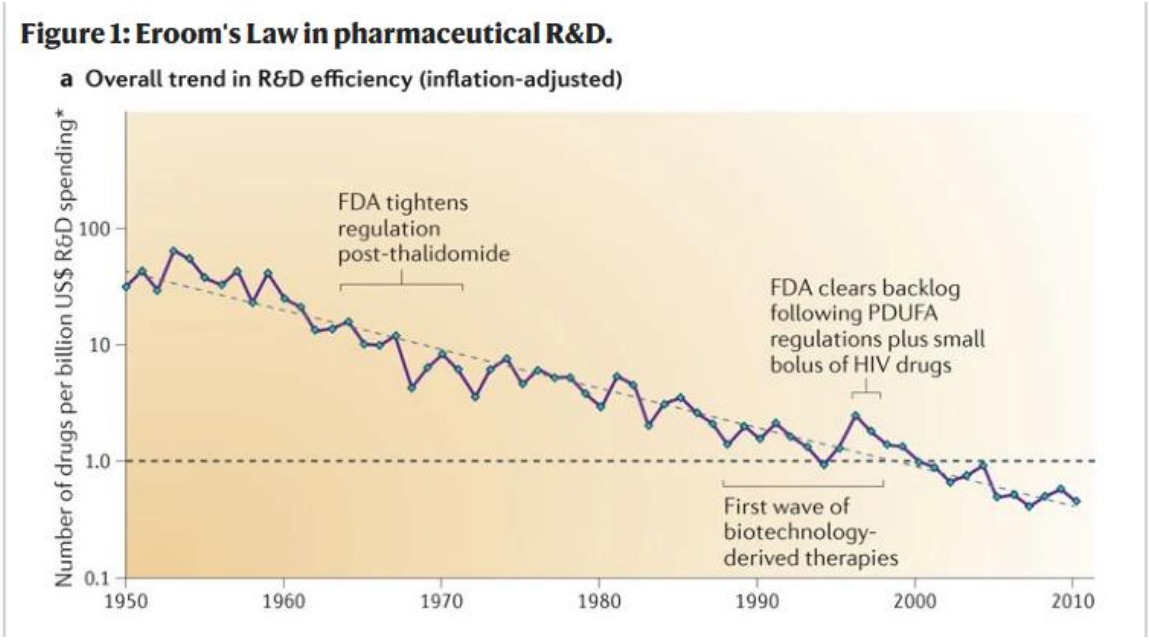
Another piece of evidence: Eroom's Law



Source: Scannell et al, 2012, p. 192.

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The debate goes on

Resetting the Innovation Clock: Endogenous Growth through Technological Turnover*

Philippe Aghion[1] Antonin Bergeaud[2]

Timo Boppart[3] Jean-Félix Brouillette[4]

March 20, 2025

Argument here: firms may run into diminishing returns, but new entries of young and "hungry" firms and the exit of "old and tired" firms inject fresh oxygen into the innovation process.

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Are the lower-hanging fruits the right metaphor?

The counter-argument: the growing scientific base of technology creates taller and taller ladders, so that what were once high-hanging fruits may be within easy reach.

And the best fruits may be higher up on the tree of knowledge, near the top.

Moreover, the tree is still growing.

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So what is my bottom line on the future of technological progress and innovation?

It is very simple:

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Can I be sure? No. A lot can go wrong.

But if we can understand what made us technologically creative in the past, and if the patterns of the past hold up, we can see that those conditions hold with even greater force today.

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The basic idea is very simple

Partition all "ideas" into *propositional* knowledge or knowledge "what" (science etc) and *prescriptive* knowledge or knowledge "how" (technology etc.)

Science drives technology. But technology feeds back into science (Nathan Rosenberg).

So the dynamics of innovation could be described by a *positive feedback loop* between propositional knowledge and prescriptive knowledge that possibly diverges.

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Empirical regularity: new scientific tools and instruments (technology) often drove waves of scientific advances.

Some examples:

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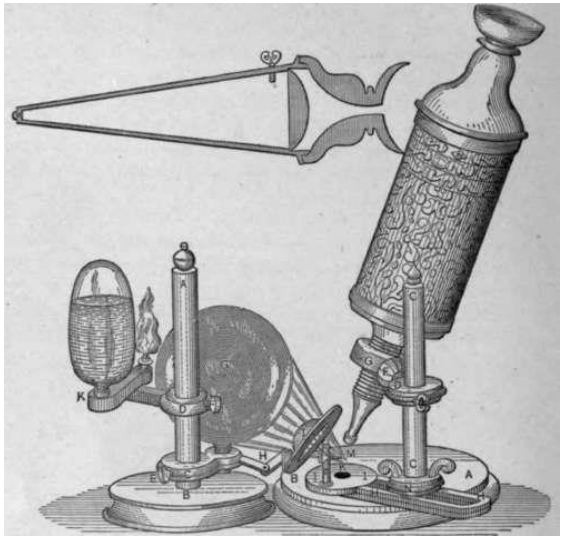
Instruments of the seventeenth century scientific revolution

Galileo's Telescope



Hooke's microscope

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Evangelista Torricelli discovered the existence of atmospheric pressure in 1643

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Otto von Guericke invented the first vacuum pump

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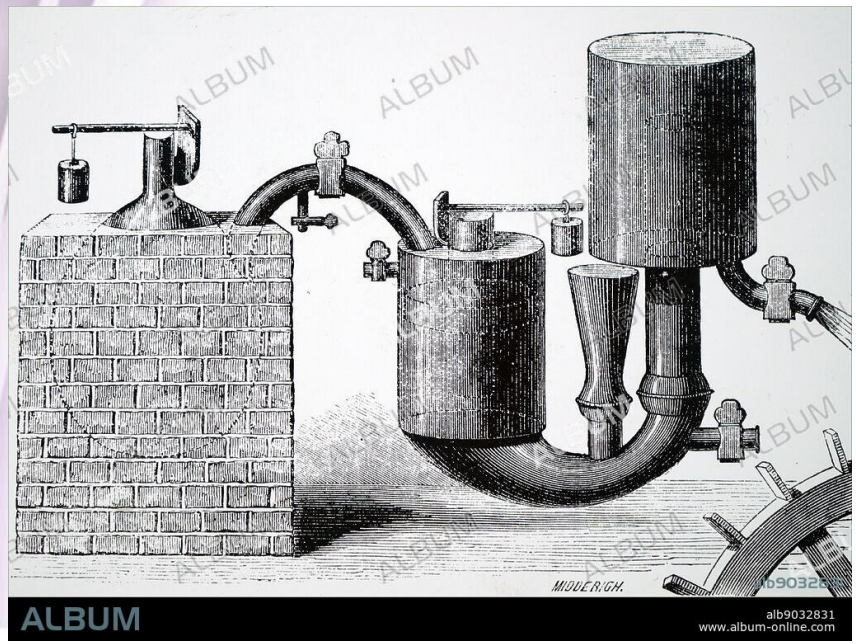
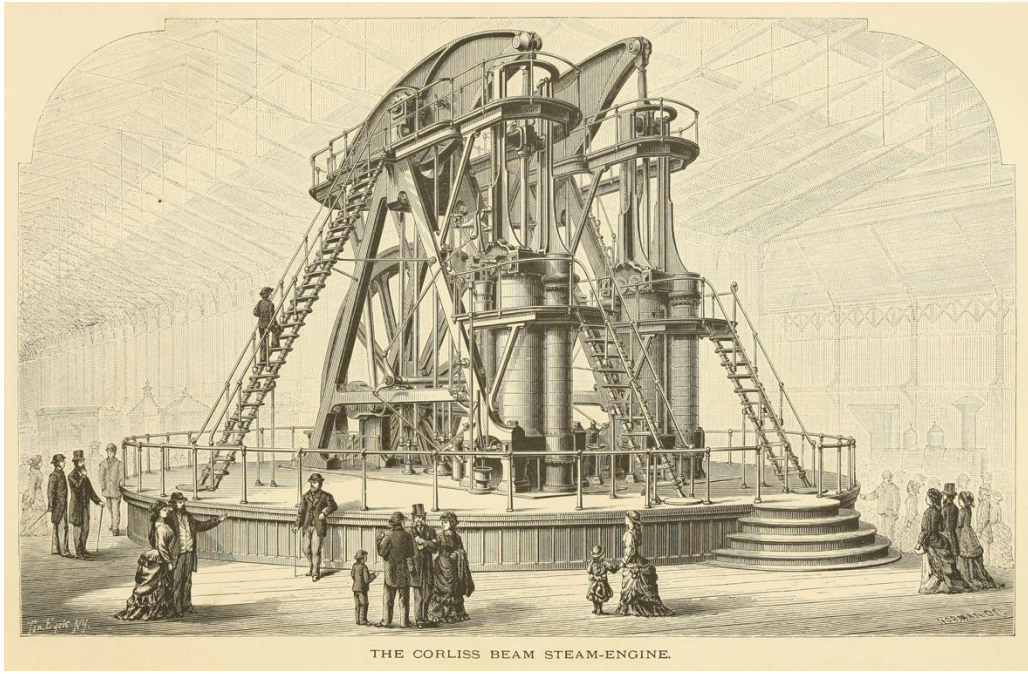
Which led to this… (completing the loop)



Denis Papin's model of steam engine (1707)



Corliss beam steam engine (1849)

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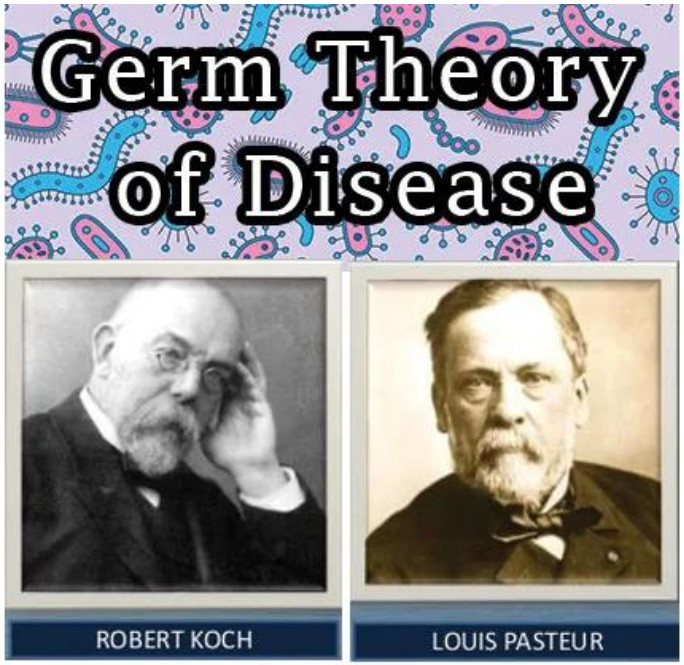
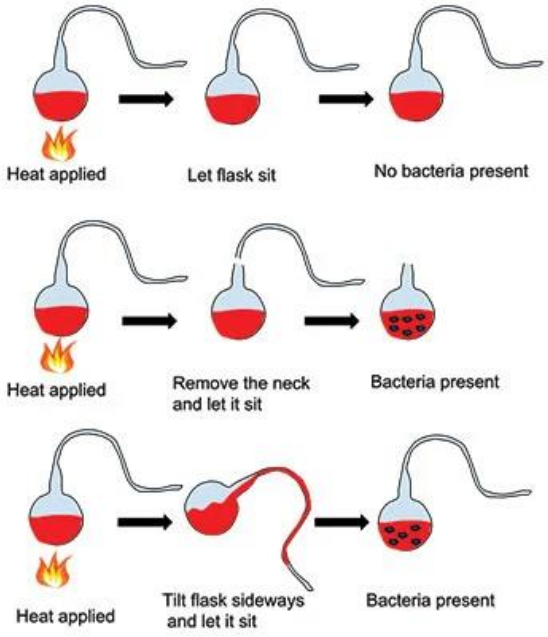
Less well-known:

The improvements in microscope technology in the nineteenth century: Joseph Jackson Lister (1786–1869), (father of the more famous surgeon), Achromatic Microscope Objective (1830). The problem he solved was that early microscopes suffered from chromatic and spherical aberrations, which caused color distortions and blurry images.

His innovation made it possible to clearly see cells, bacteria, and fine tissue structures—crucial for biological and medical research. The net result was what was arguably the most welfare enhancing discovery in history:





This feedback loop holds true a fortiori for the twentieth century.

Pick just one famous example:

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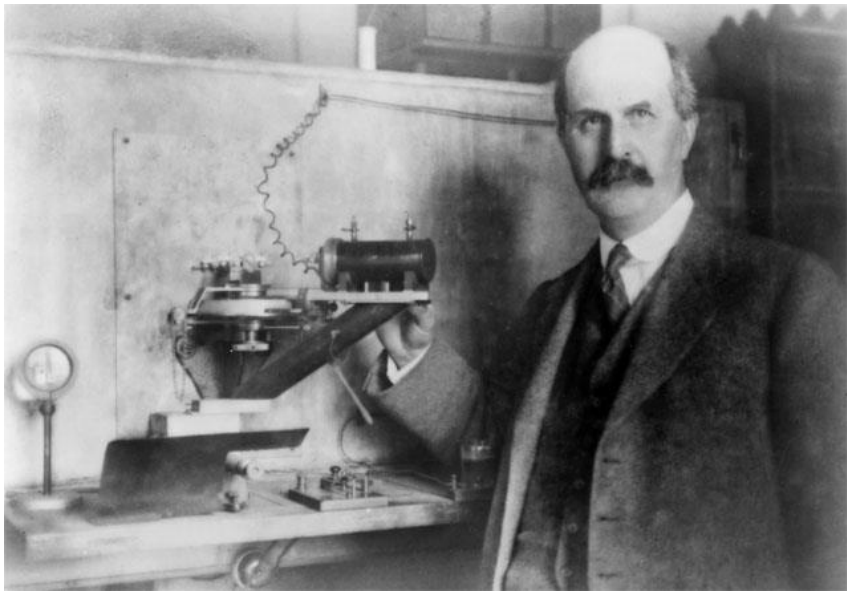
Arguably, one of the top techniques in the service of more science was the development of *x-ray crystallography*, which has led to more than 20 Nobel Prizes.

Max von Laue (1914 Nobel prize)



William Henry Bragg, English physicist, with his spectrometer, c. 1910s (1915 Nobel --- joint with his 25-year old son).

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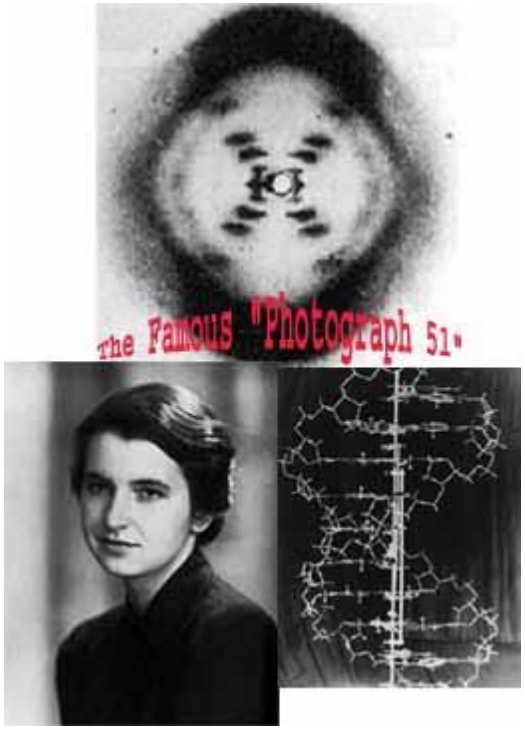
Most famous use of this technique in a major scientific advance



Rosalind Franklin's 1953 use of crystal spectroscopy to help discover the structure of DNA.

Discovery won Nobel Prize in 1962 (Franklin had died in 1958)

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What about today?

New technological tools for scientific research in the past decades.

- Vastly better telescopes, microscopes (some microscope inventors won Nobel prizes, e.g. Eric Betzig and Stefan Hell in 2014)
- High powered superfast computers
- Lasers (hundreds of uses in many fields; at least 4 Nobel prizes for developments, most obvious in 1964 to Charles H. Townes, Nicolay G. Basov, and Aleksandr M. Prokhorov)
- CRISPR–Cas Genome Editing (Nobel in 2020 to Jennifer Doudna and Emmanuelle Charpentier)

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Is AI the mother of all GPT's?

Whatever else AI will do to our world, it is clearly a fabulous RA!

"AI is the best research assistant ever devised because it can instantly analyze vast amounts of information, identify patterns, and generate insights far beyond human capacity, drastically accelerating discovery. Its ability to automate tedious tasks, synthesize complex data, and provide real-time recommendations makes it indispensable for researchers across all fields."

Written by Chatgpt in less than 20 seconds

(Nobel Prize in Physics, 2024 to John Hopfield and Geoffrey Hinton)

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A very short and woefully incomplete list of the impact of AI on scientific research

Medicine: Genomic medicine; Proteomics; mRNA sequence stability; epidemiology; interpretation of radiologic imaging.

Material Science: GNoME, or Graph Networks for Materials Exploration, developed by Google DeepMind has identified 2.2 million new crystal structures.

Energy: Faster development of batteries, catalysts, photovoltaics; smart grid operation and optimizing storage.

Economics: Big Data analysis, Natural language processing, i.e., creating new data through ML.

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More generally, how does AI support science?

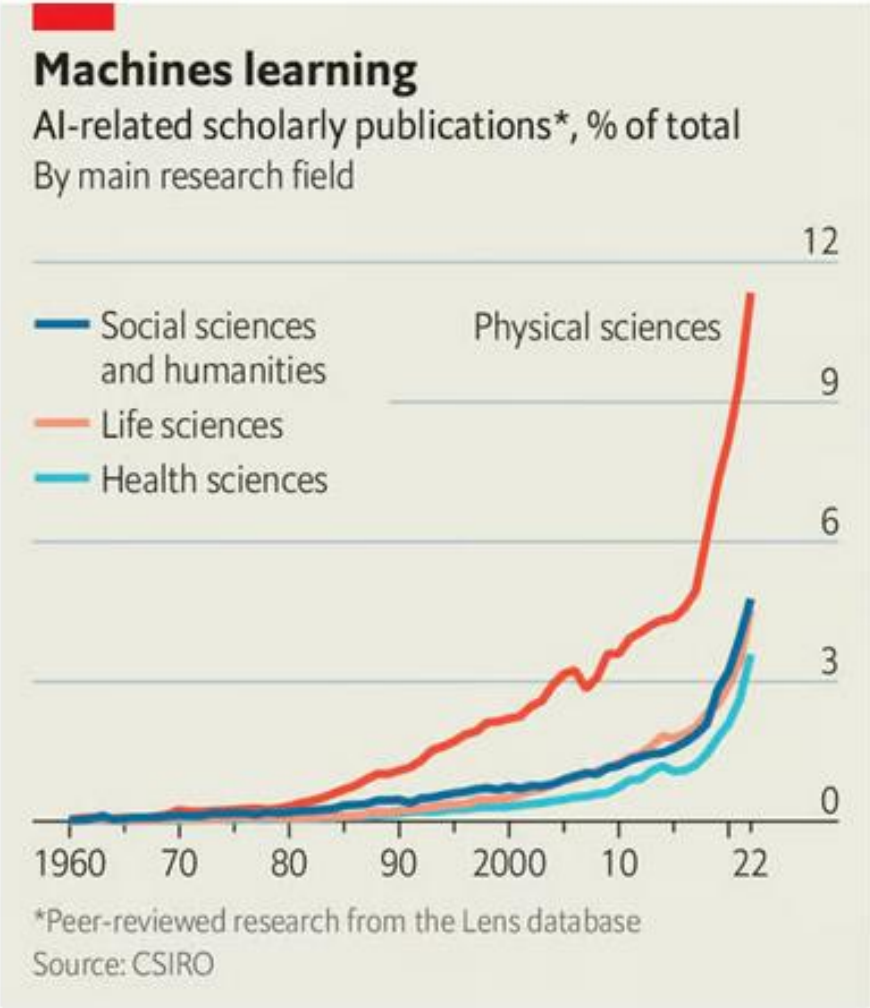

IMAGE: THE ECONOMIST

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The big question:

What can possibly go wrong?

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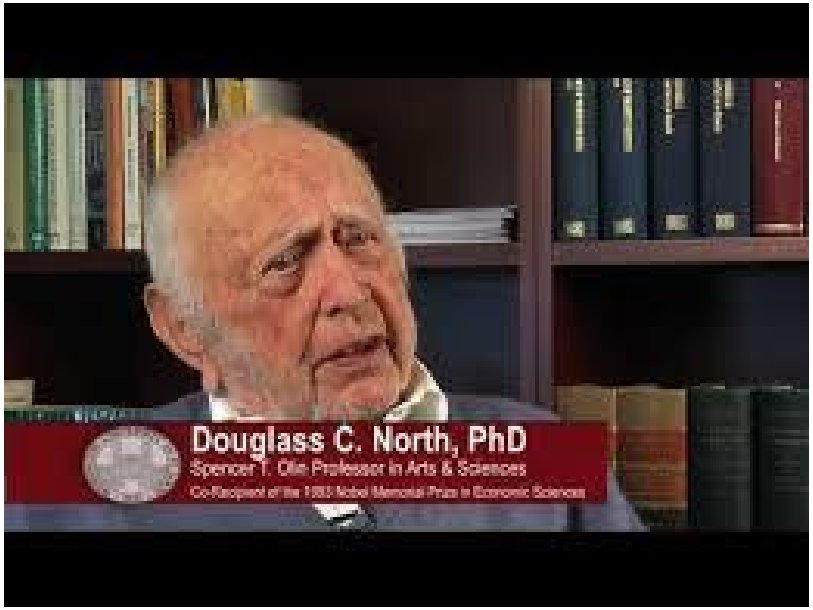
One concern: Institutions.



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What institutional environment supports innovation?

Four things matter above all to generate new useful knowledge:

- A system that *incentivizes* the upper tail of human capital, that is, the potential inventors and scientific and intellectual innovators (and does not threaten them for challenging the conventional wisdom or being eccentric or contrarian).

- A competitive, open, and free *market for ideas*, in which both the supply side and the demand side are decentralized and where no single entity has too much "market power."

- Freedom of movement. Creative persons and original thinkers should be able to move about and locate wherever they choose and where they can be most productive.

- A government that is "goldilocks" --- not too controlling and not too absent.

Progress requires the right institutions:

These conditions were met to an ever-increasing extent in early modern Europe (1450-1750), and this is the main force behind the ever-faster intellectual progress, that eventually gave us Spinoza and Hume, James Watt and Adam Smith, Antoine Lavoisier and Leonhard Euler, Alessandro Volta and Ludwig van Beethoven.

[See my *Culture of Growth*]

But do these conditions hold today?

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Today, the incentives for innovators in propositional knowledge are still there

Despite many shortcomings, the market for ideas today provides unprecedented rewards and incentives to successful intellectual innovators:

- Financial Security (tenure) in Universities and research institutes, named chairs.
- Prizes and awards from the Nobel and Abel prizes down to small and inexpensive recognitions such as membership in learned academies, honorary degrees, and small prizes for "best paper."
- Name recognition and fame through mass media, both print and electronic.
- (For a very few) riches through patents and successful start-ups.

Some of these incentives came into being after 1500, but before 1900 they were puny compared to what we have today. First Nobels in 1901. Fields medal in 1936.

Yet there are sources of concern:

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One source of concern: Dynamics of Institutional adaptation

We need to worry about institutional change, and specifically whether institutions will adapt fast enough to a rapidly changing technological environment. In the past they usually did, but slowly.

Evolutionary theory suggests that adaptation to a changing environment is quite possible, provided the environment does not change too fast. But sudden radical discontinuous “shocks” may lead to mass extinctions and catastrophes.

The acceleration in the rate of technological change recent decades is therefore a source of concern.

All the more so: the acceleration in the rate of acceleration.

Can institutions adapt in time? Particular concern: political institutions may become more polarized due to social media.

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Other sources of concern

Fragmentation: The world is still politically fragmented and competitive and becoming more so. Why is this important? Competition between nations has been conducive to scientific and technological progress, as Edward Gibbon and David Hume knew and as the Sputnik effect (among many others) attests. But this is a knife-edge problem --- fragmentation can lead to disasters (e.g., Aug. 1914). It also is correlated with nationalism and the likelihood of war (between 1500 and 2000 there were only 60-70 years in which there was no "major" conflict (> 1000 dead per year) in Europe.

Economic Nationalism: Aggressive economic nationalism (sanctions, tariffs and NTB's, and support for "strategic industries") is costly and may slow down progress seriously.

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More concerns:

Populism: One of the main features of populism is anti-elitism. This may be understandable in some cases, as at times intellectual elites have admittedly been smug and arrogant. But populism tends to de-value intellectuals, scientists and academics. The likelihood is that populist politics will throw away the baby of progress with the bathwater of elitism (and usually replace them with a much worse elite). Often combined with autocracies that are inimical to free research and the free market for ideas (Putin, Orban, Erdogan, Xi).

Xenophobia: Immigrants have been shown to have been a major boon to native-born workers and punch above their weight in cutting-edge innovative firms. But anti-immigrant movements (based less on real economic interest than on intolerance, disinformation and prejudice) have become increasingly influential.

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Failures in the market for ideas

Mis- and disinformation proliferates. We cannot be sure that in a market driven by electronic social media "good ideas" drive out bad ones. Conspiracy theories and crackpot beliefs may end up leading to major social and economic effects (e.g., anti-vax movements, "de-growth" advocates and technophobic hysteria peddlers) and lead to bimodal distributions of beliefs. These distributions tend to be rather stable due to "confirmation bias" [dismissing evidence that seemingly contradicts once prior beliefs].

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How mobile is upper-tail human capital today?

Until recently, the international market for successful scientists and top quality (and potentially innovative) personnel was free and highly competitive, in part because the US used to have an open-door policy for top-quality foreign academics, inventors and entrepreneurs, and a decentralized, highly-competitive system of high-end research organizations.

Top (and not so top) U.S. Universities, hospitals, research institutes, and cutting-edge hi-tech firms are full of foreign names.

If misguided immigration policies will make countries less hospitable to footloose scientists and engineers, they will go elsewhere.

In conclusion, there is no place for unbridled optimism about the future of western industrialized countries

As Freud said with masterly understatement in his *The Future of an Illusion*, "While mankind has made continual advances in its control over nature and may be expected to make still greater ones, it is not possible to establish with certainty that a similar advance has been made in the management of human affairs."

The IMF has warned that the biggest threat to the world economy is "geopolitical risk": rising protectionism, neo-nationalism, know-nothingism, populism, obscurantism, and technophobia.

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The most serious “headwind” is NOT the national debt or the aging of the population as Gordon contends.

It is this:

‘Against stupidity, the gods themselves contend in vain.’ (Friedrich Schiller)

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Thank you

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