I very much hope that the class will not get through all, or even most of these. Think of them as supports for the discussion I hope the class will have, rather than the skeleton of and an *aide mÃ©moire* for a lecture. But you never know how a class will go: time and chance happeneth to us all

Econ 210a: 2023-01-25 We 13:00 PST: DeLong

- This week's readings:
  - **Michael Kremer**. 1993. "Population Growth & Technological Change: One Million B.C. to 1990." *Quarterly Journal of Economics* <http://www/jstor.org/stable/2118405>
  - **Moses Finley**. 1965. "Technical Innovation and Economic Progress in the Ancient World." *Economic History Review*, pp. 29-45. <https://www-jstor-org.libproxy.berkeley.edu/stable/2591872>
  - **J. Vernon Henderson, Adam Storeygard, and David N. Weil**. 2012. "Measuring Economic Growth from Outer Space." American Economic Review 102 (April): 994-1028. <https://www-jstor-org.libproxy.berkeley.edu/stable/23245442>
- How far can we get with just "two heads are better than one"?
- Why, culturally (and institutionally?) the pre-1770 near-stagnation in global technology?
- How Good Are Cross-Country (& Cross-Time) NIPA Estimates?

Technological Roots of Growth

The Ideas Stock *H* & Its Growth Rate *h*

I define the worldwide value *H* of the stock of useful human ideas about manipulating nature and organizing humans invented, discovered, developed, deployed, and diffused—call it "technology", from τέχνη, *tekhne*, techniques or skills; and λόγος, *logos*, logic or rules—as:

$$H \propto y\sqrt{P} \text{ normalized to } H_{1870} = 1$$

Guesses

Guesses at Global Longest-Run Global Economic Growth

Date	Real Income/ Capita y	Popula-tion P (millions)	Total Income Y (billions)	Ideas Stock Level H	Ideas Growth Rate h		Population Growth n	Efficiency-Growth g
-8000	$1,200	2.04	$2.4	0.037	0.003%	Neolithic revolution	0.006%	0.000%
-6000	$900	5.09	$4.6	0.043	0.009%	**"Tribal" mode of production**	0.046%	-0.014%
-4000	$900	10.5	$9	0.062	0.018%	Final start of "urbanization"?	0.036%	0.000%
-3000	$900	15	$14	0.075	0.018%	Start of Bronze-Literacy age	0.037%	0.000%
-1500	$900	37	$33	0.117	0.030%	**Bronze-Literacy mode of pro-**	0.060%	0.000%
-1000	$900	50	$45	0.136	0.030%	Start of Iron age	0.060%	0.000%
-400	$900	103	$93	0.195	0.060%	"Ancient" mode of domination	0.120%	0.000%
150	$900	200	$180	0.272	0.060%	High Antiquity	0.121%	0.000%

Why $\sqrt{}$?

- Answers?

800	$900	240	$216	0.297	0.014%		Late-Antiquity Pause	0.028%	0.000%
1000	$900	296	$266	0.330	0.052%		**Feudal mode of production**	0.105%	0.000%
1500	$900	500	$450	0.429	0.052%		Commercial-Gunpowder-Empi	0.105%	0.000%
1770	$1,100	750	$825	0.643	0.149%		Imperial-Commercial Revolutio	0.150%	0.074%
1870	$1,300	1299	$1,689	1.000	0.442%		**Steampower mode of produc**	0.550%	0.167%
1930	$3,000	1909	$5,727	3.000	1.714%		**Second-Industrial-Revolutior**	0.641%	1.394%
1975	$6,000	3678	$22,069	9.000	2.269%		**Mass-Production mode of pr**	1.457%	1.540%
2020	$12,000	7566	$90,794	27.000	2.342%		**Global-Value-Chain mode of**	1.603%	1.540%
2100	$50,000	10000	$499,990	129.333	1.958%	?	Into the Future?	0.349%	1.784%

Dangers of Excessive Quantification

John Maynard Keynes warned us against carrying this too far:

Approximate statistical comparisons depending on some broad element of judgment rather than of strict calculation… may possess significance and validity within certain limits. But the proper place for such things... lies within the field of historical and statistical description, and their purpose should be to satisfy historical or social curiosity... of a similar character to the statement that Queen Victoria was a better queen but not a happier woman than Queen Elizabeth—a proposition not without meaning and not without interest, but unsuitable as material for the differential calculus. Our precision will be a mock precision if we try to use such partly vague and non-quantitative concepts as the basis of a quantitative analysis...

Major Features

Guesses at Global Longest-Run Global Economic Growth

Date	Real Income/ Capita y	Popula- tion P (millions)	Total Income Y (billions)	Ideas Stock Level H	Ideas Growth Rate h			Population Growth n	Efficiency- Growth g
-8000	$1,200	2.04	$2.4	0.037	0.003%		Neolithic revolution	0.006%	0.000%
-6000	$900	5.09	$4.6	0.043	0.009%		**"Tribal" mode of production**	0.046%	-0.014%
-4000	$900	10.5	$9	0.062	0.018%		Final start of "urbanization"?	0.036%	0.000%
-3000	$900	15	$14	0.075	0.018%		Start of Bronze-Literacy age	0.037%	0.000%
-1500	$900	37	$33	0.117	0.030%		**Bronze-Literacy mode of pro**	0.060%	0.000%
-1000	$900	50	$45	0.136	0.030%		Start of Iron age	0.060%	0.000%
-400	$900	103	$80	0.195	0.060%		"Ancient" mode of domination	0.120%	0.000%
150	$900	200	$180	0.272	0.060%		High Antiquity	0.121%	0.000%
800	$900	240	$216	0.297	0.014%		Late-Antiquity Pause	0.028%	0.000%
1000	$900	296	$266	0.330	0.052%		**Feudal mode of production**	0.105%	0.000%
1500	$900	500	$450	0.429	0.052%		Commercial-Gunpowder-Empi	0.105%	0.000%
1770	$1,100	750	$825	0.643	0.149%		Imperial-Commercial Revolutio	0.150%	0.074%
1870	$1,300	1299	$1,689	1.000	0.442%		**Steampower mode of produc**	0.550%	0.167%
1930	$3,000	1909	$5,727	3.000	1.714%		**Second-Industrial-Revolutior**	0.641%	1.394%
1975	$6,000	3678	$22,069	9.000	2.269%		**Mass-Production mode of pr**	1.457%	1.540%
2020	$12,000	7566	$90,794	27.000	2.342%		**Global-Value-Chain mode of**	1.603%	1.540%
2100	$50,000	10000	$499,990	129.333	1.958%	?	Into the Future?	0.349%	1.784%

1. **The Neolithic Revolution** from -8000 to -6000
2. **The glacial pace of technological progress in the past**—1870 to 2010 we saw, in an average year, 200 times the $\dot{h}$ of the early Agrarian Age. (And, of course, growth from a much, much higher pace.)
3. Nevertheless, the **large cumulative magnitude of technological progress**.
4. **The acceleration of growth in the early Agrarian Age** -6000 to the year 1
5. **The Late-Antiquity Pause** from 1 (actually 150) to 800
6. **The Mediæval Recovery**
7. **The Imperial-Commercial Age** step-up in growth over 1500 to 1770.
8. **The British Industrial Revolution Age** from 1770 to 1870.
9. **Modern Economic Growth** from 1870 to 2010.
10. **The Population Explosion and Demographic Transition** from 1770 to 2100.
11. **Whatever is going on now**—if global warming and other problems do not interrupt Modern Economic Growth, what do we have to look forward to for the world of 2100?
12. **Is this a misguided intellectual enterprise**—focusing on H, and taking it to be something real and important rather than a distracting mental-fictional cloud-castle that does more to confuse than to enlighten us?

Aristotle: THE Philosopher

And This Is the Lot of Humanity

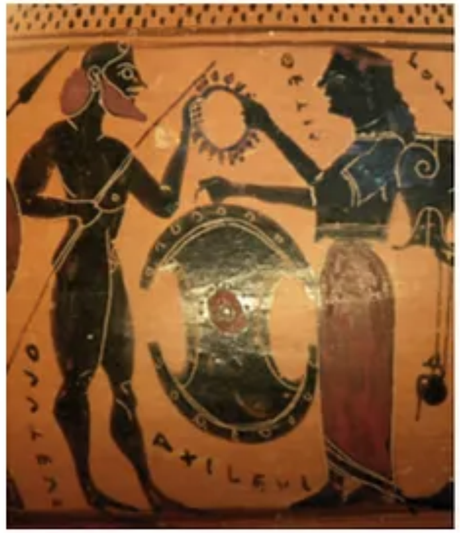
For, literally, millennia…

- "the master of those who know", as Dante called him…
- Interested in *everything*—except economic growth
- Scroll I of his *Politics*
  - "household management" = oiko-nomos = economics
  - In order: bossing slaves, raising children, directing your wife, knowing market conditions

Unless…

A household… [needs] property as instruments for living. And... a slave is living property.… If every tool could accomplish its own work, obeying or anticipating the will of others, like the statues of Daidalos, or the tripods of Hephaistos, which, says the poet Homer, "of their own accord entered the assembly of the Gods;" if, in like manner, the shuttle would weave and the plectrum touch the lyre without a hand to guide them, chief workmen would not want servants, nor masters slaves…

The Tripods [Self-Propelled Catering Carts] of Hephaistos…



Homer: "Thetis of the Silver Feet…"

Akhilleus Needs Weapons! And Mom Steps in:

Thetis of the silver feet came to the house of Hephaistos,
imperishable, starry, and shining among the immortals,
built in bronze for himself by the god of the dragging footsteps.

She found him sweating as he turned here and there to his bellows
busily, since he was working on twenty tripods
which were to stand against the wall of his strong-founded dwelling.
And he had set golden wheels underneath the base of each one
so that of their own motion they could wheel into the immortal
gathering, and return to his house: a wonder to look at.
These were so far finished, but the elaborate ear handles
were not yet on. He was forging these, and heating the chains out.

As he was at work on this in his craftsmanship and his cunning
meanwhile the goddess Thetis the silver-footed drew near him…

Glacial-Frozen Technology Before 1500

Date	Technological Ideas-Stock Growth Rate h	Technological Ideas Stock Level H (1870 = 1)	Average Annual Real Income per Capita y	Total Human Population L (millions)	Total Real World Income Y (billions)
-48000		0.0256	$1,200	1	$1.20
-8000	0.0011%	0.040	$1,200	2.5	$3.0
-6000	0.011%	0.051	$900	7	$6.3
-3000	0.013%	0.074	$900	15	$14
-1000	0.030%	0.14	$900	50	$45
1	0.061%	0.25	$900	170	$153
800	0.022%	0.30	$900	240	$216
1500	0.052%	0.43	$900	500	$450
1770	0.149%	0.64	$1,100	750	$825
1870	0.442%	1.0	$1,300	1300	$1,690
2010	2.125%	19.6	$10,526	7600	$80,000
2100	2.000%	118.4	$58,518	9000	$526,665

Near-Stasis with "Efflorescences"

Near-Stasis with "Efflorescences"

The Ice Breaks After 1500

Date	Technological Ideas-Stock Growth Rate h	Technological Ideas Stock Level H (1870 = 1)	Average Annual Real Income per Capita y	Total Human Population L (millions)	Total Real World Income Y (billions)
-48000		0.0256	$1,200	1	$1.20
-8000	0.0011%	0.040	$1,200	2.5	$3.0
-6000	0.011%	0.051	$900	7	$6.3
-3000	0.013%	0.074	$900	15	$14
-1000	0.030%	0.14	$900	50	$45
1	0.061%	0.25	$900	170	$153
800	0.022%	0.30	$900	240	$216
1500	0.052%	0.43	$900	500	$450
1770	0.149%	0.64	$1,100	750	$825
1870	0.442%	1.0	$1,300	1300	$1,690
2010	2.125%	19.6	$10,526	7600	$80,000
2100	2.000%	118.4	$58,518	9000	$526,665

1770	0.149%	0.64	$1,100	750	$825
1870	0.442%	1.0	$1,300	1300	$1,690
2010	2.125%	19.6	$10,526	7600	$80,000
2100	2.000%	118.4	$58,518	9000	$526,665

Explosion After 1870

Date	Technological Ideas-Stock Growth Rate h	Technological Ideas Stock Level H (1870 = 1)	Average Annual Real Income per Capita y	Total Human Population L (millions)	Total Real World Income Y (billions)
-48000		0.0256	$1,200	1	$1.20
-8000	0.0011%	0.040	$1,200	2.5	$3.0
-6000	0.011%	0.051	$900	7	$6.3
-3000	0.013%	0.074	$900	15	$14
-1000	0.030%	0.14	$900	50	$45
1	0.061%	0.25	$900	170	$153
800	0.022%	0.30	$900	240	$216
1500	0.052%	0.43	$900	500	$450
1770	0.149%	0.64	$1,100	750	$825
1870	0.442%	1.0	$1,300	1300	$1,690
2010	2.125%	19.6	$10,526	7600	$80,000
2100	2.000%	118.4	$58,518	9000	$526,665

And If We Go Further?

Date	Technological Ideas-Stock Growth Rate h	Technological Ideas Stock Level H (1870 = 1)	Average Annual Real Income per Capita y	Total Human Population L (millions)	Total Real World Income Y (billions)
-73000			$1,200	0.005	
-68000	0.030%	0.008	$1,200	0.1	$0.12
-48000	0.002%	0.011	$1,200	0.2	$0.24
-8000	0.003%	0.036	$1,200	2	$2.4
-5000	0.006%	0.043	$900	5	$4.5
-3000	0.027%	0.074	$900	15	$14
-1000	0.030%	0.136	$900	50	$45
1	0.061%	0.250	$900	170	$153
800	0.016%	0.285	$900	220	$198
1500	0.059%	0.429	$900	500	$450
1770	0.149%	0.643	$1,100	750	$825
1870	0.442%	1.000	$1,300	1300	$1,690
2010	2.159%	20.557	$11,600	6900	$80,040
2100	2.000%	142.035	$70,176	9000	$631,583
2200	2.000%	1049.502	$518,534	9000	$4,666,804
2300	2.000%	423399.302	$209,191,441	9000	$1,882,722,970

- We all know what exponential growth looks like…
- What does a "singularity" look like?
- Where does exponential growth logistic?
- And what about the "Great Filter"?

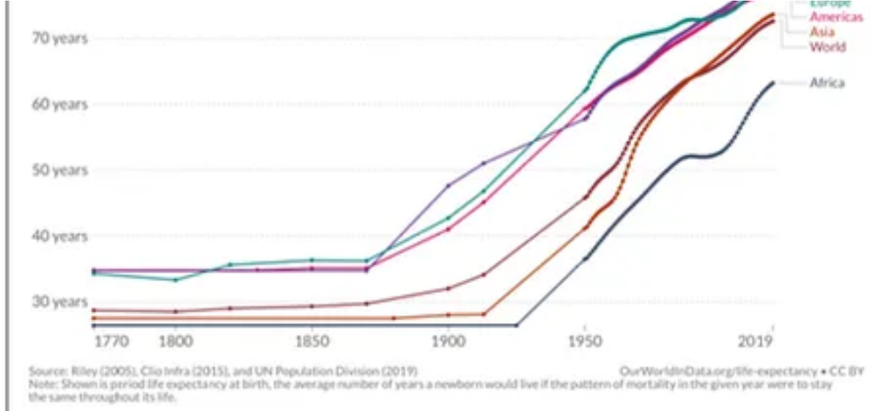
Artificial Means of Birth Control, Life Expectancy, & Female Literacy

- These things have great consequences

Why Did the Pace of Ideas Growth Use to Be So Slow? & How Fast Is It Now, Really?

"Ancient" Ain't "Primitive" or "Unsophisticated": Could we teach:

- Themistokles or Augustus much about
- Sophokles much about drama?
- Gorō Nyūdō Masamune much about making swords?
- Phryne much about presentation-of-self-as-



for demography

- They trigger the "demographic transition"
- The fall in birth rates and the drive toward ZPG…

politics?

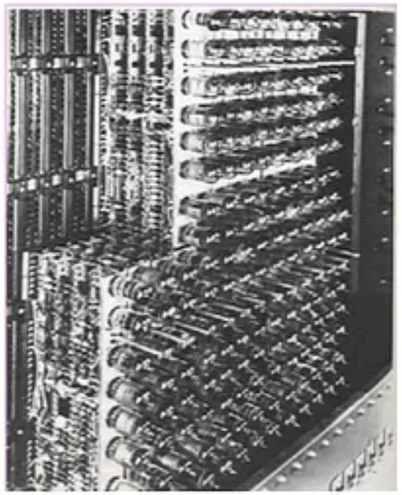
- Homer much about writing epic?
- Li Bai much about writing poetry?
- Gaius Julius Caesar or Leonidas Agiades much about generalship?

celebrity?

- Michelangelo Buonarroti much about painting ceilings?
- Praxiteles much about sculpture?
- Johann Sebastian Bach much about music?

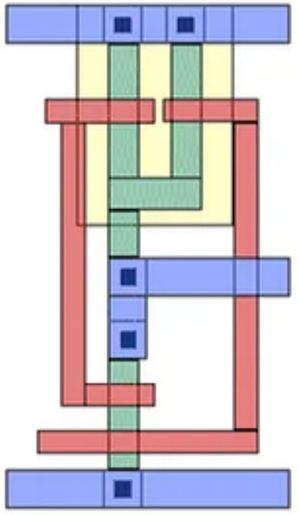
NOW: Each of These Is a Single Logic Gate

Vacuum Tubes in the IBM 701



A glass tube filled with a vacuum:

- A NAND gate: 1" in diameter x 4" long
- Today a NAND gate is 100 nm x 150 nm in a surface layer on a 0.75 mm wafer
  - Silicon atom: 0.2 nm on a side
- We could fit 5 trillion NAND gates inside one of these
- Bottom Line:
  - We not only produce commodities much more cheaply
  - We also produce very different commodities
  - Commodities that could not have been produced at any price more than two generations ago are incredibly cheap today



Readings & Questions…

Michael Kremer. 1993. "Population Growth & Technological Change: One Million B.C. to 1990." *Quarterly Journal of Economics* <http://www/jstor.org/stable/2118405>

Moses Finley. 1965. "Technical Innovation and Economic Progress in the Ancient World." *Economic History Review*, pp. 29-45. <https://www-jstor-org.libproxy.berkeley.edu/stable/2591872>

J. Vernon Henderson, Adam Storeygard, and David N. Weil. 2012. "Measuring Economic Growth from Outer Space." **American Economic Review** 102 (April): 994-1028. <https://www-jstor-org.libproxy.berkeley.edu/stable/23245442>

- How far can we get with just "two heads are better than one"?
- Why, culturally (and institutionally?) the pre-1770 near-stagnation in global technology?
- How Good Are Cross-Country (& Cross-Time) NIPA Estimates?

Kremer: One Million BC…

Michael Kremer (1993), "Population Growth and Technological Change: One Million B.C. to 1990," Quarterly Journal of Economics 108:3 (August), pp. 681-716 <http://www.jstor.org/stable/2118405>

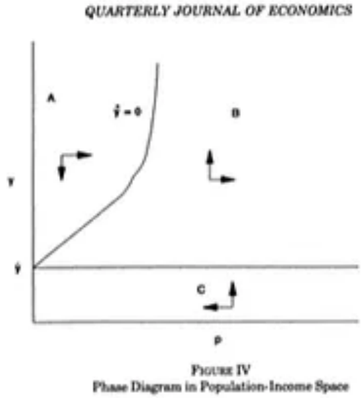


FIGURE IV
Phase Diagram in Population-Income Space

Kremer: One Million BC

- The evidence is scanty
  - It does seem to point to "two heads are better than one" for a while…
  - Plus Malthusianism seems well established
    - Up until the demographic transition…
- Is the phase diagram useful?

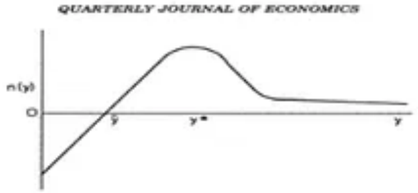


FIGURE II
Population Growth Versus Income

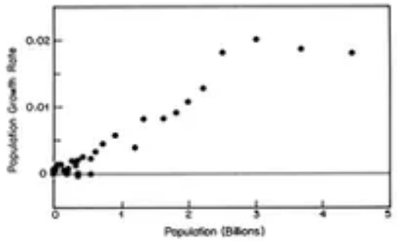


FIGURE I
Population Growth Versus Population

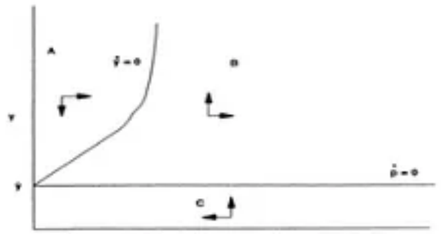


FIGURE IV
Phase Diagram in Population-Income Space

Michael Kremer (1993): *Population Growth & Technological Change: One Million B.C. to 1990*

- Innovation—change in log technology—proportional to population
  - Humans as anthology intelligence
  - What alternatives?
- Malthusian population dynamics
  - Plus a possible

Combining the research and population determination equations is straightforward. Since population is limited by technology, the growth rate of population is proportional to the growth rate of technology. Since the growth rate of technology is proportional to the level of population, the growth rate of population must also be proportional to the level of population. To see this more formally, take the logarithm of the population determination equation, (2), and differentiate with respect to time:

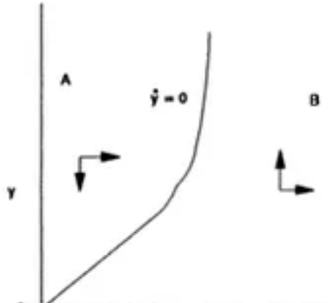
$$\frac{\dot{p}}{p} = \frac{1}{1-\alpha}\frac{\dot{A}}{A}. \quad (4)$$

Substitute in the expression for the growth rate of technology, from (3), to obtain

- $\frac{dP}{dt} = kP^2$
- Kremer's model generates very strong conclusions:
- Eventual modern economic growth inevitable, and inescapable
- Major determinants of when MEG takes hold:
  - improvements in communication-diffusion,
  - in science-innovation, and
  - in the triggers of the demographic transition
- The conclusions are strong, but only as strong as the model. How strong is the

Kremer: What Does Economic Modeling Have to Contribute?

QUARTERLY JOURNAL OF ECONOMICS



Why is ideas growth what it is in each age?

- Kremer: Two Heads Are Better than One
  - Ideas growth should be STEM labor force raised to some power
  - Implies—with demographic transition—an eventual breakthrough
  - How well does it fit?
    - Breaks down with the Late-Antiquity Pause…

- Plus a possible (eventual) demographic transition
- Is this reasonable?

(5) $$\frac{\dot{p}}{p} = \frac{g}{1-\alpha} p.$$

This prediction, that the growth rate of population will be proportional to the level of population, implies much faster than exponential growth. In contrast, if there were a constant exoge-

model?

- What other state variables should be in there? Seems to work, kinda, up to the year 1…
- But then: late-antiquity pause…
- And after 1500, not really a resumption…
- & no fourth watershed-crossing since 1980…

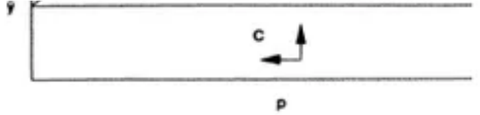


FIGURE IV
Phase Diagram in Population-Income Space

- What causes (is there) rough stability within ages?
  - Gatherer-hunter, agrarian pre-literate, agrarian literate, late-antiquity pause, commercial-imperial, industrial revolution, modern economic growth

Finley: Why Are These Post-Literacy Pre-Imperial-Commercial Revolution Ideas Growth Rates so Slow?

Moses Finley:

"Two facts[:]...

"[(1)] The ancient world was very unambiguous about wealth. Wealth was a good thing, a necessary condition for the good life, and that was all there was to it. There was no nonsense about wealth as a trust, no subconscious guilt feelings, no death-bed restitutions of usury....

"[(2)] There was a basis for more technical advance—in production—than was actually made.

"Why did productivity then not advance markedly, if the interest, the knowledge, and the necessary intellectual energy would seem to have been present? The question cannot be dismissed simply by pointing to alternative values, not, at least, when one of those was a very powerful desire for wealth and for large-scale consumption…"

- Lots of low-hanging technological fruit in agrarian-age civilizations
- Great human ingenuity in other forms of life
- Yet discovering, developing, and deploying *productive technologies* does not seem to be a high priority for, well, anyone
- Why not?

- Finley writes a think piece, based overwhelmingly on the *literary* evidence

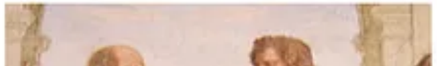
Finley: Why Are These Post-Literacy Pre-Imperial-Commercial Revolution Ideas Growth Rates so Slow?

- Assertions about responsiveness to fashion and imperatives of craftsmanship…
  - Lots of incremental improvements
  - Little wide dissemination
- "Intellectually (or scientifically) speaking, there was a basis for more technological advance—in production—than was actually made…"
- "Archimedes' practical inventions, I hasten to add, were military and were made only under the extraordinary and irresistible stimulus of the siege of his native Syracuse by the Romans."
- "it is this unanimity which justifies the argument from silence…"

- "Why did neither the Ptolemies nor the Sicilian tyrants nor the Roman emperors systematically (or even spasmodically) turn their engineers to the search for higher productivity, at least in those sectors of the economy which produced the royal revenues?
- "Whatever the answer, it was not lack of capital (or lack of authority). Funds, manpower and technical skills were made available (and wasted) in vast and ever increasing amounts for roads, public buildings, water supply, drainage and other amenities, but not for production.
- "Of course, the effort to increase productivity might have proved unsuccessful - but it was never even attempted…"

Aristotle

- Aristotle of Stagira was not an idiot. For two thousand years people called him "the philosopher"—as if there was only one…



Aristotle

- Shepherds "…the laziest [of men]… lead an idle life… get their subsistence without trouble from

- On acquisition:
  - "A general account has now been given of the various forms of acquisition: to consider them minutely, and in detail, might be useful for practical purposes; but to dwell long upon them would be in poor taste.... There are books on these subjects by several writers ..."
  - The "natural art of acquisition" has "a boundary fixed, just as there is in the other arts; for the instruments of any art are never unlimited..."
  - "There are two sorts of wealth-getting... one is a part of household management, the other is retail trade: the former necessary and honorable, while that which consists in exchange is justly censured; for it is unnatural, and a mode by which men gain from one another..."
- On Slavery:
  - "[I]f every instrument could accomplish its own work, obeying or anticipating the will of others, like the statues of Daedalus, or the catering serving carts of Hephaestus... the shuttle would weave and the plectrum touch the lyre without a hand to guide them, chief workmen would not want servants, nor masters slaves....
  - "But is there any one thus intended by nature to be a slave, and for whom such a condition is expedient and right?... There is no difficulty in answering this question... that some should rule and others be ruled is a thing not only necessary, but expedient; from the hour of their birth, some are marked out for subjection, others for rule...

tame animals..."?

- Aristotle's story of Thales of Miletos and his corner of the olive-press-rental market on Khios: Aristotle is saying "we could get rich (or richer) with little effort, but that is not an important or proper thing to do..."
- Note: Aristotle's "limit" is probably the full-time year-round labor of at least fifty people, at today's OECD wage levels some $3,000,000 a year: in one sense very, very few of us will ever come near to Aristotle's point of satiation; in another sense every single one of us has already gone far beyond Aristotle's limit

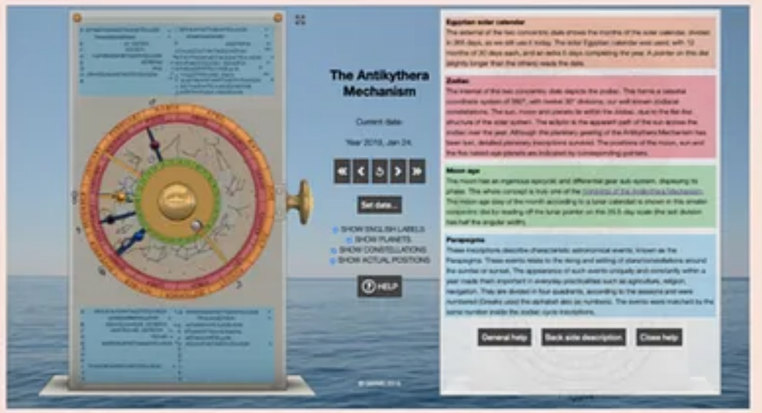
But: The Antikythera Mechanism

- Built between -150 and -70. Rhodes 13" x 7" x 4" wooden box.
- Gears—largest 5" in diameter
- Wikipedia:
  - 37 gear wheels enabling it to follow the movements of the Moon and the Sun through the zodiac, to predict eclipses and even to model the irregular orbit of the Moon, where the Moon's velocity is higher in its perigee than in its apogee.
  - This motion was studied in the 2nd century BC by astronomer Hipparchus of Rhodes, and it is speculated that he may have been consulted in the machine's construction.
  - The knowledge of this technology was lost at some point in antiquity.
  - Similar technological works later appeared in the medieval Byzantine and Islamic worlds, but works with similar complexity did not appear again until the development of mechanical astronomical clocks in Europe in the fourteenth century…

2021-02-02

Antikythera Mechanism

Figure 12. This picture shows the help menu for the front side (courtesy of Markos Skoulatos and Georg Brandl).



Antikythera Mechanism

Figure 13. This picture shows the help menu for the rear side (courtesy of Markos Skoulatos and Georg Brandl).

Seneca vs. Posidonius on Whether Technology Is Philosophy

Lucius Annaeus Seneca Minor (64): *Moral Letters to Lucilius 90: On the Part Played by Philosophy in the Progress of Man*:
SELECTIONS: "That philosophy discovered the arts of which life makes use in its daily round I refuse to admit.... I, for my part, do not hold that philosophy devised these shrewdly-contrived dwellings of ours which rise story upon story, where city crowds against city, any more than that she invented the fish-preserves, which are enclosed for the purpose of saving men's gluttony from having to run the risk of storms....

Was it philosophy that taught the use of keys and bolts? Nay, what was that except giving a hint to avarice?... All this sort of thing was born when luxury was being been...

On another point also I differ from Posidonius, when he holds that mechanical tools were the invention of wise men.... Nay, the sort of men who discover such things are the sort of men who are busied with them.... The hammer [and] the tongs... were both invented by some man whose mind was nimble and keen, but not great or exalted; and the same holds true of any other discovery which can only be made by means of a bent body and of a mind whose gaze is upon the ground....

Which man, pray, do you deem the wiser—the one who invents a process for spraying saffron perfumes to a tremendous height from hidden pipes, who fills or empties canals by a sudden rush of waters, who so cleverly constructs a dining-room with a ceiling of movable panels that it presents one pattern after another, the roof changing as often as the courses,—or the one who proves to others, as well as to himself, that nature has laid upon us no stern and difficult law when she tells us that we can live without the marble-cutter and the engineer, that we can clothe ourselves without traffic in silk fabrics, that we can have everything that is indispensable to our use, provided only that we are content with what the earth has placed on its surface? If mankind were willing to listen to this sage, they would know that the cook is as superfluous to them as the soldier....

Posidonius then passes on to the farmer.... This trade also, he declares, is the creation of the wise, —just as if cultivators of the soil were not even at the present day discovering countless new methods of increasing the soil's fertility!... He even degrades the wise man by sending him to the mill.... Posidonius came very near declaring that even the cobbler's trade was the discovery of the wise man....

Not so; these early inventions were thought out by no other class of men than those who have them in charge to-day. We know that certain devices have come to light only within our own memory..., windows which admit the clear light through transparent tiles,.. baths with pipes let into their walls for the purpose of diffusing the heat.... marble... rounded and polished masses of stone.... Or our signs for whole words, which enable us to take down a speech, however rapidly uttered, matching speed of tongue by speed of hand?

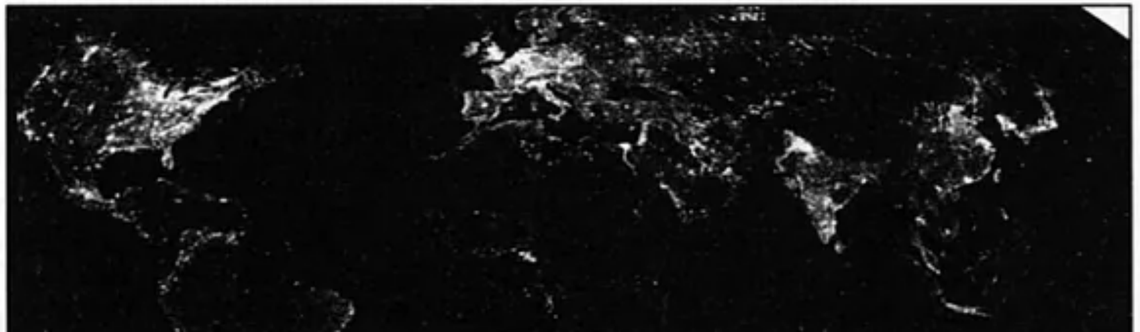
All this sort of thing has been devised by the lowest grade of slaves...

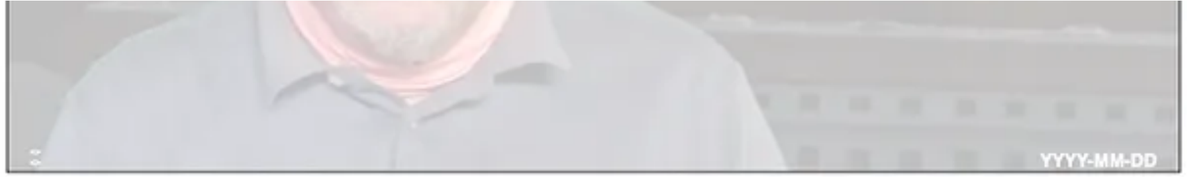
READING: Seneca vs. Posidonius on Whether Technology Is Philosophy
<https://braddelong.substack.com/p/reading-seneca-vs-posidonius-on-whether> 2021-04-03 5a

Template

How Good Are Cross-Country (& Cross-Time) NIPA Estimates?: The Case of Lights

J. Vernon Henderson, Adam Storeygard, and David N. Weil. 2012. "Measuring Economic Growth from Outer Space." ***American Economic Review*** 102 (April): 994-1028. <https://www-jstor-org.libproxy.berkeley.edu/stable/23245442>





How Good Are Cross-Country (& Cross-Time?) NIPA Estimates?

TABLE 2—BASELINE RESULTS FOR THE WORLD: 1992–2008; GROWTH IN REAL GDP (*constant LCU*)

	ln(GDP) (1)	ln(GDP) (2)	ln(GDP) (3)	ln(GDP) (4)	ln(GDP) (5)	ln(GDP) (6)	ln(GDP) (7)	ln(GDP) (8)
ln(lights/area)	0.277*** [0.031]	0.2618*** [0.0344]	0.2662*** [0.0314]	0.286*** [0.034]	0.282*** [0.046]		0.166*** [0.051]	0.284*** [0.030]
ln(lights/area) sq.		−0.0058 [0.0060]						
ln(count top-coded + 1)			0.0115* [0.0059]					
ln(unlit)			−0.0124 [0.0122]					
Spatial Gini				0.165 [0.194]				
ln(KWH)						0.283*** [0.047]	0.201*** [0.041]	
Observations	3,015	3,015	3,015	3,015	1,853	1,853	1,853	3,015
Countries	188	188	188	188	128	128	128	188
(Within country) R^2	0.769	0.769	0.770	0.769	0.757	0.767	0.782	0.770

Notes: All specifications include country and year fixed effects. Column 8 excludes regions with gas flares. Robust standard errors, clustered by country, are in brackets.

For Next Time: Domination & Unfreedom

Branko Milanovic, Peter H. Lindert, and Jeffrey G. Williamson. 2011. "Pre-Industrial Inequality." *Economic Journal* 121 (March): 255-272. <https://www-jstor-org.libproxy.berkeley.edu/stable/41057775>

Alberto Alesina, Paola Giuliano, & Nathan Nunn. 2013. "On the Origins of Gender Roles: Women and the Plough." *Quarterly Journal of Economics* 128 (May): 469–530. <https://www-jstor- org.libproxy.berkeley.edu/stable/26372505>

Karl Marx and Friedrich Engels. 1848. *Manifesto of the Communist Party* <http://www.marxists.org/archive/marx/works/1848/communist-manifesto/>

Nathan Nunn. 2008. "The Long-Term Effects of Africa's Slave Trades." *Quarterly Journal of Economics* 123 (May): 139-176 <https://www-jstor-org.libproxy.berkeley.edu/stable/25098896>

Nordhaus (1997): *Do Real-Output & Real-Wage Measures Capture Reality? The History of Lighting Suggests Not*

William D. Nordhaus (1997): *Do Real-Output & Real-Wage Measures Capture Reality? The History of Lighting Suggests Not* <http://www.nber.org/chapters/c6064>

The Lighting Budget of Thomas Jefferson

Figure that 7% of Jefferson's salary went to lighting. Of course, Jefferson did not live on his salary: he inherited 20 slaves and land in a total estate valued at 12000 dollars from his father, and he inherited a further 135 slaves and 11000 acres of land from his father-in-law in an estate worth perhaps six times as much. He spent all the

- Use labor & resources to produce matter & energy in forms useful for our purposes…
- Pdty Growth = Δln(Input Prices) - Δln(Output Prices) + {value of ability to produce new & better goods}
- It's the last term {} that is the problem…
- The question of the usefulness of pdty growth

income and more: he died bankrupt, with assets—land and slaves—valued at $100,000, and equal debts.

For this substantial expenditure—7% of his Secretary-of-State salary—Jefferson received as much illumination as is delivered by a 60-watt incandescent light bulb run for 30 minutes a day. Modern efficient lighting technologies deliver that service for 0.15 cents.

Figuring a multiple of 25 for a back-of-the-envelope multiplication of the price level since 1790, what cost Jefferson 250 dollars in 1790 costs us 5 cents: 1/5000 as much. And, of course, we are richer: 15 times richer is the standard back-of-the-envelope number.

For the same share of our income, we can produce, buy, and use 75,000 times as much illumination as back in Jefferson's day.

How much extra utility to we derive from our ability to get so much artificial illumination so cheaply?

Lighting Numbers

Table 1.3 Efficiency of Different Lighting Technologies

Device	Stage of Technology	Approximate Date	Lighting Efficiency (lumens per watt)	Lighting Efficiency (lumen-hours per 1,000 Btu)
Open fire[a]	Wood	From earliest time	0.00235	0.69
Neolithic lamp[a]	Animal or vegetable fat	38,000–9000 B.C.	0.0151	4.4
Babylonian lamp[a]	Sesame oil	1750 B.C.	0.0597	17.5
Candle[a]	Tallow	1800	0.0757	22.2
	Sperm	1800	0.1009	29.6
	Tallow	1830	0.0757	22.2
	Sperm	1830	0.1009	29.6
Lamp	Whale oil[a]	1815–45	0.1346	39.4
	Silliman's experiment: Sperm oil[a]	1855	0.0784	23.0
	Silliman's experiment: Other oils[a]	1855	0.0575	16.9
Town gas	Early lamp[a]	1827	0.1303	38.2
	Silliman's experiment[a]	1855	0.0833	24.4
	Early lamp[a]	1875–85	0.2464	72.2
	Welsbach mantle[a]	1885–95	0.5914	173.3
	Welsbach mantle[a]	1916	0.8685	254.5
Kerosene lamp	Silliman's experiment[a]	1855	0.0498	14.6
	19th century[a]	1875–85	0.1590	46.6
	Coleman lantern[a]	1993	0.3651	107.0
Electric lamp				
Edison carbon	Filament lamp[a]	1883	2.6000	762.0
Advanced carbon	Filament lamp[a]	1900	3.7143	1,088.6
	Filament lamp[a]	1910	6.5000	1,905.0
Tungsten	Filament lamp[a]	1920	11.8182	3,463.7
	Filament lamp[a]	1930	11.8432	3,471.0
	Filament lamp[a]	1940	11.9000	3,487.7
	Filament lamp[a]	1950	11.9250	3,495.0
	Filament lamp[a]	1960	11.9500	3,502.3
	Filament lamp[a]	1970	11.9750	3,509.7
	Filament lamp[a]	1980	12.0000	3,517.0
	Filament lamp[a]	1990	14.1667	4,152.0
Compact fluorescent	First generation bulb[a]	1992	68.2778	20,011.1

Note: The modern unit of illumination is the lumen which is the amount of light cast by a candle at one foot.

The Lighting Budget of Thomas Jefferson

Figure that 7% of Jefferson's salary went to lighting. Of course, Jefferson did not live on his salary: he inherited 20 slaves and land in a total estate valued at 12000 dollars from his father, and he inherited a further 133 slaves and 11000 acres of land from his father-in-law in an estate worth perhaps six times as much. He spent all the income and more: he died bankrupt, with assets—land and slaves—valued at $100,000, and equal debts.

For this substantial expenditure—7% of his Secretary-of-State salary—Jefferson received as much illumination as is delivered by a 60-watt incandescent light bulb run for 30 minutes a day. Modern efficient lighting technologies deliver that service for 0.15 cents.

Figuring a multiple of 25 for a back-of-the-envelope multiplication of the price level since 1790, what cost Jefferson 250 dollars in 1790 costs us 5 cents: 1/5000 as much. And, of course, we are richer: 15 times richer is the standard back-of-the-envelope number.

For the same share of our income, we can produce, buy, and use 75,000 times as much illumination as back in Jefferson's day.

How much extra utility to we derive from our ability to get so much artificial illumination so cheaply?

Official Statistics & Reality

Table 1.4 Basic Data on the True Price of Light

Date	True Price of Light: Per 1,000 Lumens (current prices) (1)	True Price of Light: Per 1,000 Lumens (1992 prices) (2)	Index, Real Prices (1800 = 100) (3)	Light Price in Terms of Labor (hours of work per 1,000 lumen hours) (4)	Official Price Indexes: CPI (1800 = 100) (5)	Official Price Indexes: Light I (1800 = 100) (6)	Official Price Indexes: Light II (1800 = 100) (7)	Price Ratio (true to official price): Light I (8)	Price Ratio (true to official price): Light II (9)
ca. 500,000 B.C.				56					
50,000–9000 B.C.				50					
1750 B.C.				41.5					
1800	40.293	429.628	100.000	5.387	100.0	100.00	100.00	1.00	1.00
1818	40.873	430.117	100.114	5.332	101.3	91.71	93.71	0.92	0.92
1827	18.632	249.985	58.186	3.380	79.5	86.16	86.16	1.86	1.86
1830	18.315	265.656	61.835	2.999	73.5	72.96	72.96	1.61	1.61
1835	40.392	596.089	138.745	7.569	72.3	69.81	69.81	0.70	0.70
1840	30.943	626.774	145.888	5.057	62.8	66.04	66.04	0.72	0.72
1850	23.199	397.362	92.490	2.998	62.3	59.75	59.75	1.04	1.04
1855	29.777	466.980	107.298	3.344	68.9	64.15	64.15	0.87	0.87
1860	10.963	176.505	41.083	1.152	66.2	61.64	61.64	2.27	2.27
1870	4.036	41.390	9.634	0.330	104.0	84.28	84.28	8.41	8.41
1880	5.015	65.905	15.340	0.489	81.5	57.86	57.86	4.63	4.63
1883	9.228	122.791	28.581	0.750	80.1	55.97	55.97	2.44	2.44
1890	1.573	23.241	5.410	0.133	72.2	45.28	45.28	11.60	11.60
1900	2.692	42.906	9.987	0.2204	66.9	55.03	55.03	8.24	8.24
1910	1.384	19.350	4.550	0.0921	75.5	56.57	56.57	16.47	16.47
1916	0.346	4.282	0.997	0.0134	86.1	88.31	88.31	102.92	102.92
1920	0.630	4.228	0.984	0.0135	158.9	194.56	194.56	124.40	124.40
1930	0.309	4.098	0.954	0.0104	132.5	93.30	93.30	73.86	73.86
1940	0.323	5.092	0.720	0.00549	111.3	85.22	65.78	106.44	82.16
1950	0.241	1.350	0.314	0.00188	190.7	84.28	82.61	140.66	104.49
1960	0.207	0.940	0.219	0.00102	234.4	102.28	70.89	199.45	138.24
1970	0.175	0.608	0.142	0.00055	307.3	111.50	73.01	256.26	172.39
1980	0.447	0.730	0.170	0.00068	652.3	315.43	179.34	282.82	161.83
1990	0.600	0.618	0.144	0.00060	1,035.1	479.80	275.57	322.31	185.12
1992	0.124	0.124	0.029	0.00012	1,066.3	503.94	281.09	1,631.55	910.03

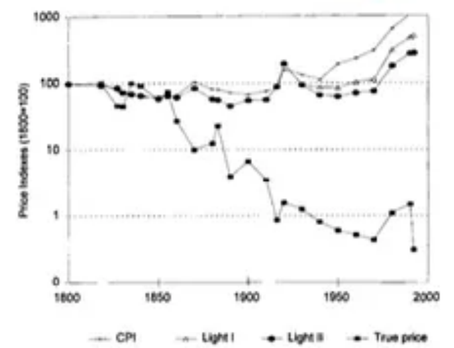


Fig. 1.4 Alternative light prices

Nordhaus Argument I

By design, price indexes can capture the small, run-of-the-mill changes in economic activity, but revolutionary jumps in tech- nology are simply ignored by the indexes. What is surprising is how pervasive the range of revolutionary products is. In this section I look at how price in- dexes treat quality change, examine the treatment of selected inventions, esti- mate the range of poorly measured consumption, and then hazard an estimate of the potential bias in real wage and real output measures… For revolutionary changes in technology, such as the introduction of major inventions, traditional techniques simply ignore the fact that the new good or service may be significantly more efficient. Consider the case of automobiles. In principle, it would be possible to link automobiles with horses so as to con- struct a price of travel, but this has not been done in the price statistics for just the reasons that the true price of light was not constructed. Similar problems arise as televisions replace cinemas, air travel replaces ground travel, and mod- ern pharmaceuticals replace snake oil.

The omission of quality change and particularly revolutionary technological change does raise the possibility that most of the action of the Age of Invention was simply missed in our traditional real-product and real-wage measures. Table 1.7 presents a selection from Jewkes, Sawers, and Stillerman's list of the one hundred great inventions (1969). Note how little of the impact of these great inventions was captured in traditional price indexes …. The approach taken here is to examine today's consumption bundle, and then to divide it into three categories. In each case, the question is how great the change in the good or service has been since the beginning of the nineteenth century:

Nordhaus Argument II

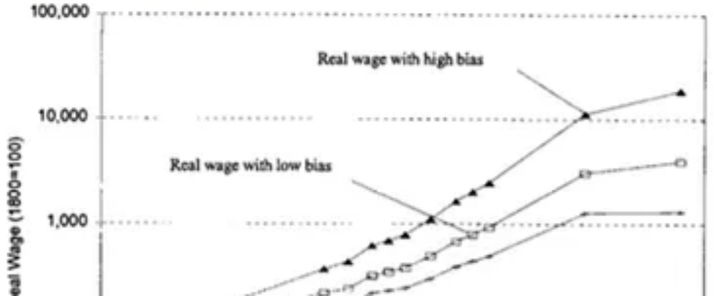
1. Run-of-the-mill changes. Changes in technology… relatively small… price indexes… miss relatively little…. Home consumption of food (such as potatoes), most clothing (such as cotton shirts), personal care (such as haircuts), furniture, printed materials (such as books), and religious activities (such as going to mass)…. More timely news, pasteurized milk, and high-tech running shoes. But the overall underestimate… is likely to be much less…

2. Seismically active sectors. Major changes in the quality of goods and provision of new goods, but… the good or service itself is still recognizably similar…. Housing… watches… personal business (including financial services and the information super- ighway), space-age toys, and private education and research.

3. Tectonic shifts. The category in which lighting is placed…. The entire nature of the production process has changed radically…. Price indexes do not attempt to capture the qualitative changes…. Household appliances (such as refrigerators and air conditioners), medical care, utilities (including heating, lighting, and other uses of electricity), telecommunications, transportation, and electronic goods… no resemblance between the consumption activity today and that in the early nineteenth century.…

Clearly, this categorization is extremely rough, and refinements would probably shift some of the sectors to different categories…. Almost three-quarters of today's consumption is radically different from its counterpart in the nineteenth century. As a result, it is likely that estimates of the growth of real consumption services is hampered by significant errors in the measurement of prices and that for almost two-fifths of consumption the price indexes are virtually useless…

Official & Nordhaus Real Wages



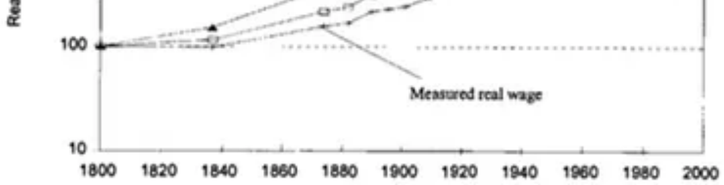


Fig. 1.8 Traditional and true real wages

Technological Roots of Growth

- Measurement: â˜š
- Major features
- Importance of â€œrobotsâ€□
- Glacially-frozen with â€œefflorescencesâ€□
- Ice-breaking
- Explosion
- What comes next?

Key Processes

- Demographic transition
- Impediments to discovery, development, deployment, and diffusion before 1870

Kremer: One Million B.C.

- Two heads are better than one
- How is this insufficient?

Finley: Technical Innovation

- Very much a â€œsubstantivistâ€□
- Civilizational effort in other directions
- But not in pushing forward deployed-and-diffused productive technology
- How to understand the Antikythera Mechanism?

Henderson: Measuring Economic Growth

- Night lights!

Nordhaus: Real Output and Real Wage Measures

- The lighting budget of Thomas Jefferson