Econ 210a: Modern Economic Growth (February 26, 2020a)

J. Bradford DeLong

Spring 2019
Evans 648
W 1:10-3:00 pm

<https://bcourses.berkeley.edu/courses/1487686/>

<https://github.com/braddelong/public-files/blob/master/econ-210a-lecture-6a.pptx>

Modern Economic Growth

The four key numbers in this course are: 0.04, 0.15, 0.44, 2.06—the annual percentage growth rates *h* of the useful-ideas stock in the Post-Writing Agrarian, Commercial Revolution, Industrial Revolution, and Modern Economic Growth Eras. (Or perhaps 0.05, 0.2, 0.9, 2.3—the numbers for "the Advanced West".) But is it really best thought of as 2.06 (or 2.3)? And why is it so much bigger than 0.44 (or 0.9)?:

Readings:

- William D. Nordhaus (1997): *Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not* <http://www.nber.org/chapters/c6064>
- Robert Gordon (2000): *Interpreting the "One Big Wave" in Long-Term Productivity Growth* <https://www.nber.org/papers/w7752.pdf>
- Peter Thompson (2001): *How Much Did the Liberty Shipbuilders Learn? New Evidence for an Old Case Study* <http://www.jstor.org/stable/pdfplus/10.1086/318605.pdf>

Let's Look at the Dual…

With prices and expenditure shares, it would seem that the calculation of economic growth is very easy:

- With perfect competition, the price decline is the TFP increase…
- Multiply expenditure shares by the price decline, and you get the savings: how much less it takes you this year to attain last year's consumption bundle
- The wedge between income growth and expenditure-weighted price declines is then economic growth: how much of additional resources do you have this year?
- Problems:
  - Whose expenditure shares?
  - What about expansions in the set of producible goods—things whose prices fall from ∞, where we do not observe the initial stages of the fall
  - "Spite" & "envy" effects—also "hits"
  - How do we become who we are?

Reading Nordhaus

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

- Conventional measures: a 15-fold increase in real first-world GDP/capita and productivity since 1800 or so…

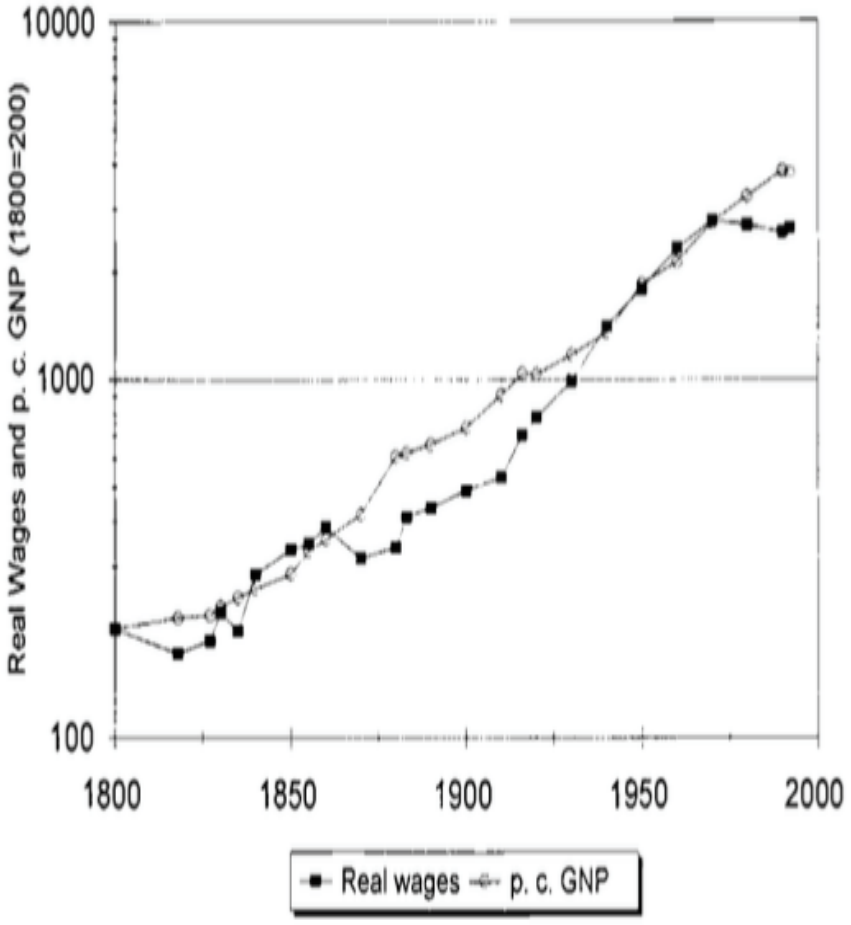


Fig. 1.1 Real wages and per capita GNP

Bill Nordhaus: Rocket Ship to the Singularity?

- A 20-fold or a 30,000-fold increase in real wages in the North Atlantic since 1800?
- Nordhaus calculates that—back in 1991—28% of consumption was "run-of-the-mill", 36% had been "seismically-active" since 1800, and 37% was in sectors that had *no effective affordable equivalent in 1800*
- Dixit-Stiglitz tells us that we multiply "ordinary" utilities by the number of varieties. Which way does that mislead us?

Table 1.8 Consumption by Extent of Qualitative Changes, 1991 ($ billion)

Sector	Run-of-the-Mill Sectors	Seismically Active Sectors	Tectonically Shifting Sectors
Food			
Home consumption	419.2		
Purchased meals		198.5	
Tobacco		47.8	
Clothing			
Apparel	208.9		
Cleaning and services		21.1	
Watches and jewelry		30.6	
Personal care			
Toilet articles		38.2	
Services	24.0		
Housing			
Dwellings		574.0	
Housing operation			
Furniture and utensils	116.3		
Appliances			25.5
Cleaning and polishing		52.8	
Household utilities			143.2
Telephone and telegraph			54.3
Other	49.6		
Medical care			656.0
Personal business			
Legal and funeral	60.3		
Financial and other		257.5	
Transportation			438.2
Recreation			
Printed	42.9		
Toys		32.3	
Electronics and other goods			84.2
Other	51.7	51.2	27.4
Private education and research		92.8	
Religious and welfare	107.7		
Total	1,080.6	1,396.8	1,428.8
Percent of total	27.7	35.8	36.6

Bill Nordhaus: Rocket Ship II

- A 5000-fold decrease in the price of light since 1800
- This is something that churned up between 1% and 5% of household budgets back in 1800
- 100-fold CPI bias in the price of light since 1800

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[b]	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[c]	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[d]	1815–45	0.1346	39.4
	Silliman's experiment: Sperm oil[e]	1855	0.0784	23.0
	Silliman's experiment: Other oils[f]	1855	0.0575	16.9
Town gas	Early lamp[g]	1827	0.1303	38.2
	Silliman's experiment[e]	1855	0.0833	24.4
	Early lamp[e]	1875–85	0.2464	72.2
	Welsbach mantle[e]	1885–95	0.5914	173.3
	Welsbach mantle[e]	1916	0.8685	254.5
Kerosene lamp	Silliman's experiment[e]	1855	0.0498	14.6
	19th century[h]	1875–85	0.1590	46.6
	Coleman lantern[i]	1993	0.3651	107.0
Electric lamp				
Edison carbon	Filament lamp[j]	1883	2.6000	762.0
Advanced carbon	Filament lamp[j]	1900	3.7143	1,088.6
	Filament lamp[j]	1910	6.5000	1,905.0
Tungsten	Filament lamp[j]	1920	11.8182	3,463.7
	Filament lamp[j]	1930	11.8432	3,471.0
	Filament lamp[j]	1940	11.9000	3,487.7
	Filament lamp[k]	1950	11.9250	3,495.0
	Filament lamp[k]	1960	11.9500	3,502.3
	Filament lamp[k]	1970	11.9750	3,509.7
	Filament lamp[k]	1980	12.0000	3,517.0
	Filament lamp[l]	1990	14.1667	4,152.0
Compact fluorescent	First generation bulb[m]	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.

Bill Nordhaus: Rocket Ship III

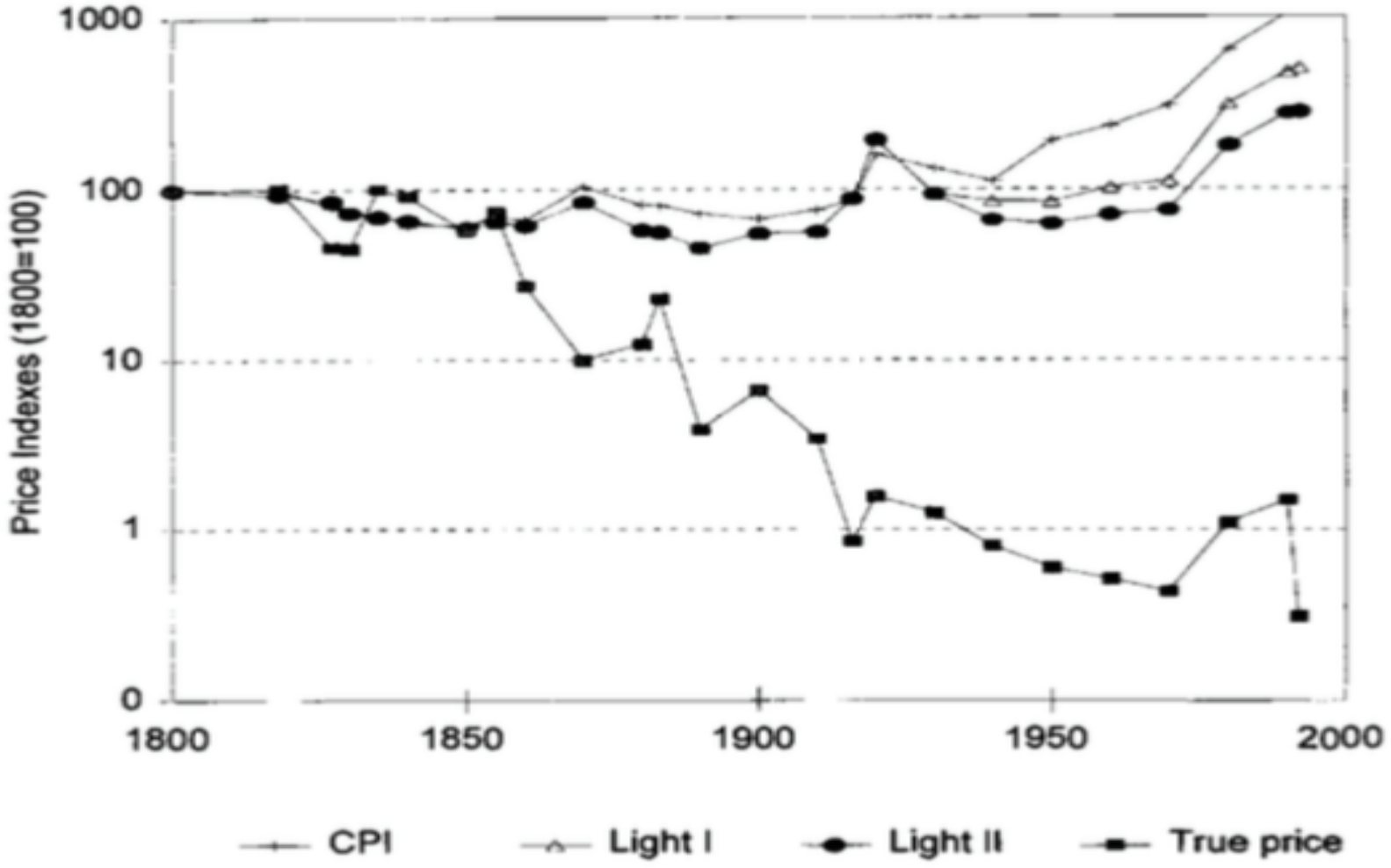
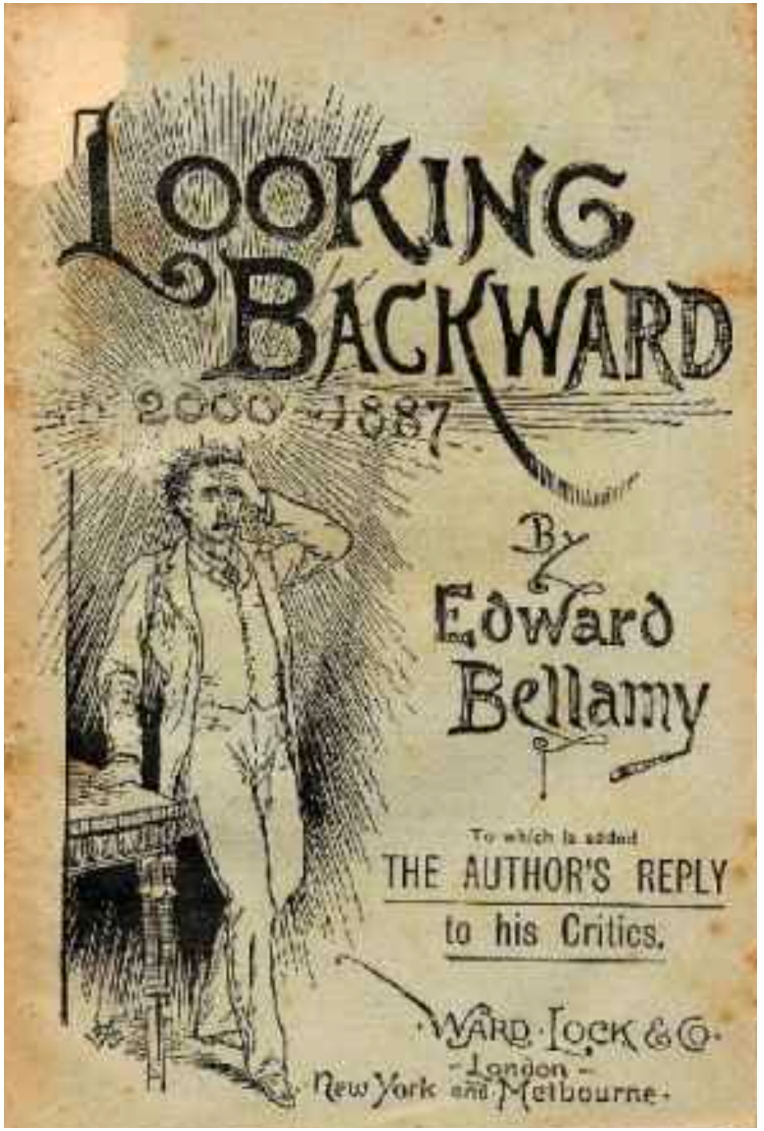


Fig. 1.4 Alternative light prices

“Do You Like Music?”

- Perhaps a better way than doing math in which to grasp the magnitude of the contribution that the changing set and mass of goods and services we can produce makes to our wealth is by reading Looking Backward, Edward Bellamy’s 1887 utopian novel. In Looking Backward the narrator—thrown forward in time from 1895 to 2000 by an unbelievable and crude plot device.
- He hears the question (p. 87): “Are you fond of music?”
- He expects his hostess to play the piano—a social accomplishment of upper-class women around 1900. To listen to music on demand then, you had to have—in your house or nearby—an instrument, and someone trained to play it. It would have cost the average worker some 2400 hours, roughly a year at a 50-hour workweek, to earn the money to buy a high-quality piano, and then there would be the expense and the time committed to piano lessons.
- But today, to listen to music-on-demand in your home, all you need is… your smartphone…



Labor-Time Values

- The labor-time value of a Steinway piano has fallen in price from 2400 average worker-hours a century ago to 1100 average worker-hours today. But if what you value is not the piano itself but the capability of listening to music at home, the cost has fallen from 2400 average worker-hours a century ago to… what?
- Maybe 10 hours?
- So when we calculate the increase in material wealth, do we count the halving of the labor-time price of the commodity (which is what Historical Statistics does); or do we count the 240-fold decrease in the real labor-time price of the capability of listening to piano music? The experiences of live and recorded music are different in kind. But are they different enough to put a serious dent in the fact that a household today can acquire the capability of listening to piano music for only 1/240 the labor time cost of a household of a century ago? And whose piano playing do you really want to listen to?

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IFIXIT —

iFixit's iPhone XS and XS Max teardown: Like the iPhone X with a couple surprises

The iPhone XS has a wild new battery design.

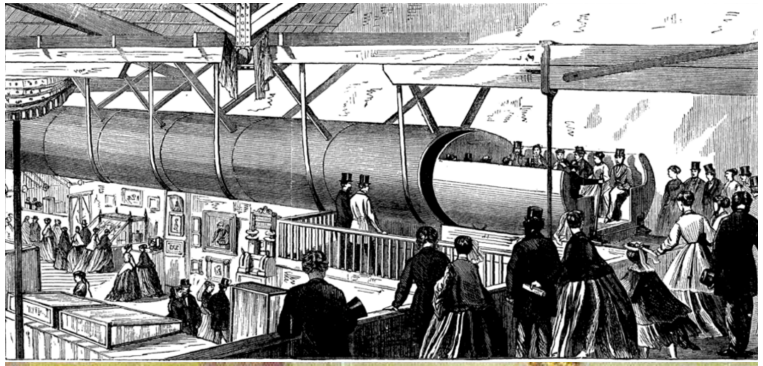
SAMUEL AXON - 9/21/2018, 10:40 AM

The iPhone XS has a different battery design than the iPhone XS Max, which has the same design as the iPhone X.

When we went hands-on with the iPhone XS and XS Max, we were mainly struck by how similar they felt to the iPhone X—particularly the iPhone XS. But it turns out that inside, it's the iPhone XS that diverges with an unusual new battery design. iFixit tore down both phones and provided analysis and gorgeous pictures as always. Be sure to check out their full teardown, but a few highlights stand out.

“The Limit of Human Felicity…”

- After answering “yes” to the question “would you like to hear some music?” Bellamy’s protagonist is stupefied to find his hostess “merely touched one or two screws… and immediately the room was 'filled with music; filled, not flooded, for, by some means, the volume of melody had been perfectly graduated to the size of the apartment. “Grand!” I cried. ‘Bach must be at the keys of that organ; but where is the organ?’ (pp. 88-89) He learns that his hostess has called the orchestra on the telephone—for in Bellamy's utopia you can dial one of four orchestras, and then put it on the speakerphone.
- Bellamy’s protagonist then says (p. 90): “If we [in the nineteenth century] could have devised an arrangement for providing everybody with music in their homes, perfect in quality, unlimited in quantity, suited to every mood, and beginning and ceasing at will, we should have considered the limit of human felicity already attained…"
- To Edward Bellamy—a self-described utopian visionary, a late-nineteenth century minister’s son from western Massachusetts—a radio that could tune into any of four stations is “the limit of human felicity.”



Tower Records

- What if someone were to take Edward Bellamy to Tower Records?
- Ooops.
- There is no Tower Records anymore, because they have been and are being eliminated by alternative and even cheaper and more efficient systems of distribution.
- Well, if we could have taken Edward Bellamy to Tower Records when it existed, his heart would have stopped. Yet we do not think of our modern ability to cheaply listen to high-fidelity go-anywhere listen-to-anything music as a remarkable or even a notable part of our economy. We do not daily give thanks for our CD collections and genuflect in front of our iPods. We in the North Atlantic today do not reflect that we have been brought to "the limit of human felicity…"
- But Edward Bellamy would think that we have…

Nordhaus, and Not Quite Among the 400

- The argument that our commodity-focused price indices miss most of the real action—that price indices focusing on the services provided would produce vastly greater estimates of long-run economic growth—is made most powerfully by William Nordhaus (1996) in his study of the economic cost of light.
- Nordhaus attempts to construct a consistent series of the real labor-time cost of illumination from the dawn of civilization until today. He concludes that the past hundred years have seen a ten thousand-fold decline in the real price of illumination. Yet the commodity-based price indices economists rely on have only captured a ten-fold decline in this real price. Nordhaus guesses that standard estimates understate "true" economic growth since 1800 by between 0.5% and 1.4% per year—an amount that cumulates to a multiplicative factor of between 3 and 15 over the past to centuries, and to a conclusion that real wages since 1900 have multiplied by a factor between 20 and 100.
- Is this credible?
- I have no problem at all with Nordhaus's conclusion. My family's income today is roughly $400,000 a year—about eight times median earnings per worker. Suppose that you stuffed me and my family into a time machine, sent us back a century to 1890, and then gave us an income equal to sixty-four times that of 1890 median per worker. We would not be among the 400 invited to the most exclusive parties in the mansions of Newport Rhode Island; but we would be among the next outer circle of 2,000 or so.
- Would we then feel as rich as we feel now? Would we be happy—or at least not unhappy—with the switch?

The Death of Nathan Meyer Rothschild

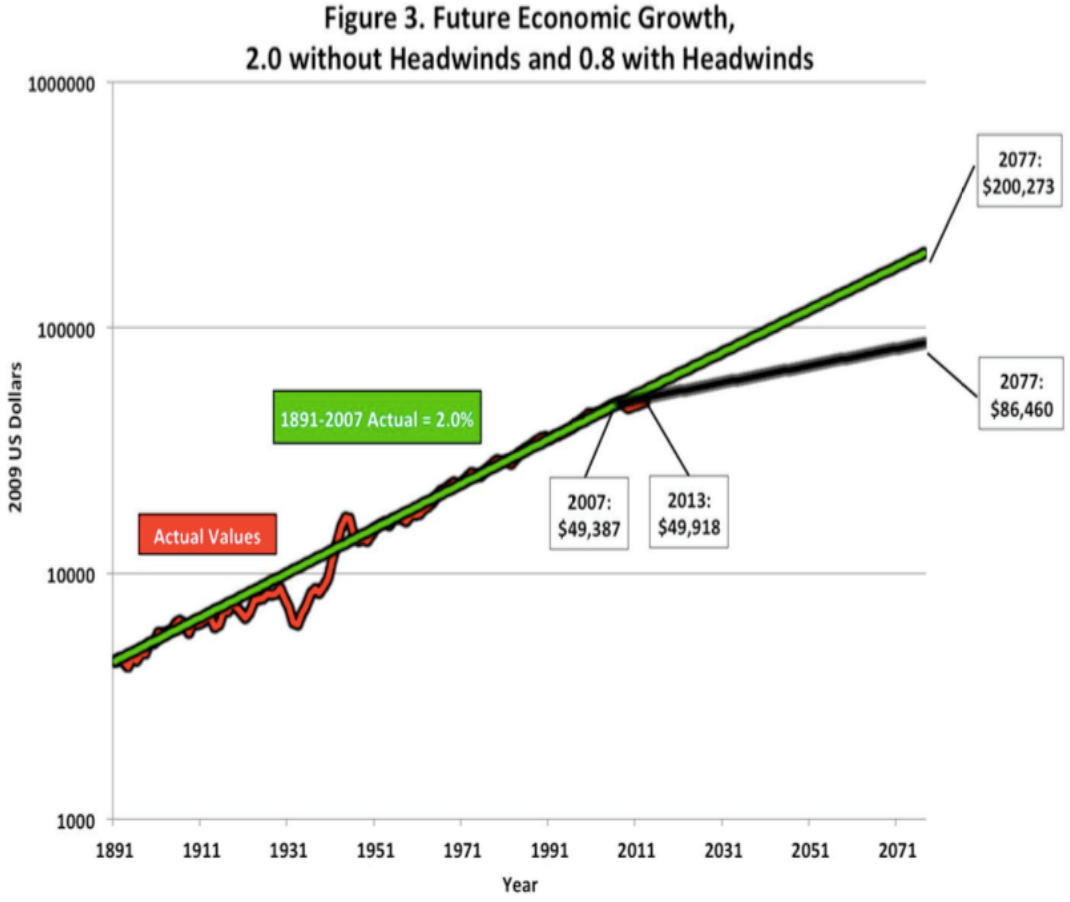
- Our power to purchase some commodities would be vastly increased: we would have at least three live-in servants, a fifteen-room house (plus a summer place), if we lived in San Francisco we would live on Nob Hill, if we lived in Boston we would live on Beacon Hill, if we lived in New York we would live on Park or Fifth Avenue.
- The answer is surely that we would not be happy and we would feel poor (although if you compared yourself to other people in 1890, you would feel very rich). I would want, first, health insurance: the ability to go to the doctor and be treated with late-twentieth-century medicines. Franklin Delano Roosevelt was crippled by polio. Nathan Meyer Rothschild—the richest man in the world in the first half of the nineteenth century—died of an infected abscess in his mid-fifties and never saw his grandchildren grow up. Without antibiotic and adrenaline shots I would now be dead of childhood pneumonia.

Questions About Nordhaus

Reading Gordon

Robert Gordon (2000): Interpreting the "One Big Wave" in Long-Term Productivity Growth <https://www.nber.org/papers/w7752.pdf>:

- Technological exhaustion occurred 40 years ago.
- "There is no need to forecast that innovation in the future will 'falter'…. The slowdown in the rate of productivity growth… occurred more than four decades ago….
- "[My] forecast assumes that innovations in the next 40 years will be developed at the same pace as the last four decades, but reasons for skepticism are provided for that prediction….
- "The… 1870 and 1900, with continuing benefits to 1972… "Second Industrial Revolution" (IR #2)…. growth rate of American productivity… [of] 2.36 percent per year, compared to 1.59 percent per year since 1972. That permanent decline of 0.8[%-points]… measure[s] the extent to which the single-dimension digital "Third Industrial Revolution" (IR #3) has fallen short of the multi-dimensional IR #2…



Global and "Western" Numbers

Longest-Run Global Economic Growth (2019)

Date	ideas Level H	Total Real World Income Y (billions)	Average Real Income per Capita y (per year)	Total Human Population L (millions)		Rate of Population and Labor Force Growth n	Rate of Efficiency-of-Labor Growth g	Rate of Ideas-Stock Growth h
-68000	1.0	$0	$1,200	0.1				
-8000	5.0	$3	$1,200	2.5		0.005%	0.000%	0.003%
-6000	6.3	$6	$900	7		0.051%	-0.014%	0.011%
-3000	9.2	$14	$900	15		0.025%	0.000%	0.013%
-1000	16.8	$45	$900	50		0.060%	0.000%	0.030%
0	30.9	$153	$900	170		0.122%	0.000%	0.061%
800	41.1	$270	$900	300		0.071%	0.000%	0.035%
1500	53.0	$450	$900	500		0.073%	0.000%	0.036%
1770	79.4	$825	$1,100	750		0.150%	0.074%	0.149%
1870	123.5	$1,690	$1,300	1300		0.550%	0.167%	0.442%
2020	2720.5	$90,000	$11,842	7600		1.177%	1.473%	2.061%

- The Commercial Revolution acceleration appears *everywhere*
  - Due to globalization
  - And especially to the "Columbian Exchange"

"Western" Numbers

Global Growth: The Industrializing West (2019)

Date	ideas Level H	Total Real Income Y (billions)	Average Real Income per Capita y (per year)	Total "West" Population L (millions)		Rate of Population and Labor Force Growth n	Rate of Efficiency-of-Labor Growth g	Increasing Resources ρ	Rate of Ideas-Stock Growth h
-68000	1.0	$0.01	$1,200	0.005					
-8000	4.5	$0.12	$1,200	0.1		0.005%	0.000%	0.000%	0.002%
-6000	4.7	$0.18	$900	0.2		0.035%	-0.014%	0.000%	0.003%
-3000	7.5	$0.45	$900	0.5		0.031%	0.000%	0.000%	0.015%
-1000	15.0	$1.80	$900	2		0.069%	0.000%	0.000%	0.035%
0	23.7	$4.50	$900	5		0.092%	0.000%	0.000%	0.046%
800	30.0	$7.20	$900	8		0.059%	0.000%	0.000%	0.029%
1500	58.9	$25.00	$1,000	25		0.163%	0.015%	0.000%	0.096%
1770	101.0	$105.00	$1,400	75		0.407%	0.125%	0.257%	0.200%
1870	252.0	$490.00	$2,800	175		0.847%	0.693%	0.405%	0.914%
2020	8439.5	$40,000.00	$50,000	800		1.013%	1.922%	0.175%	2.341%

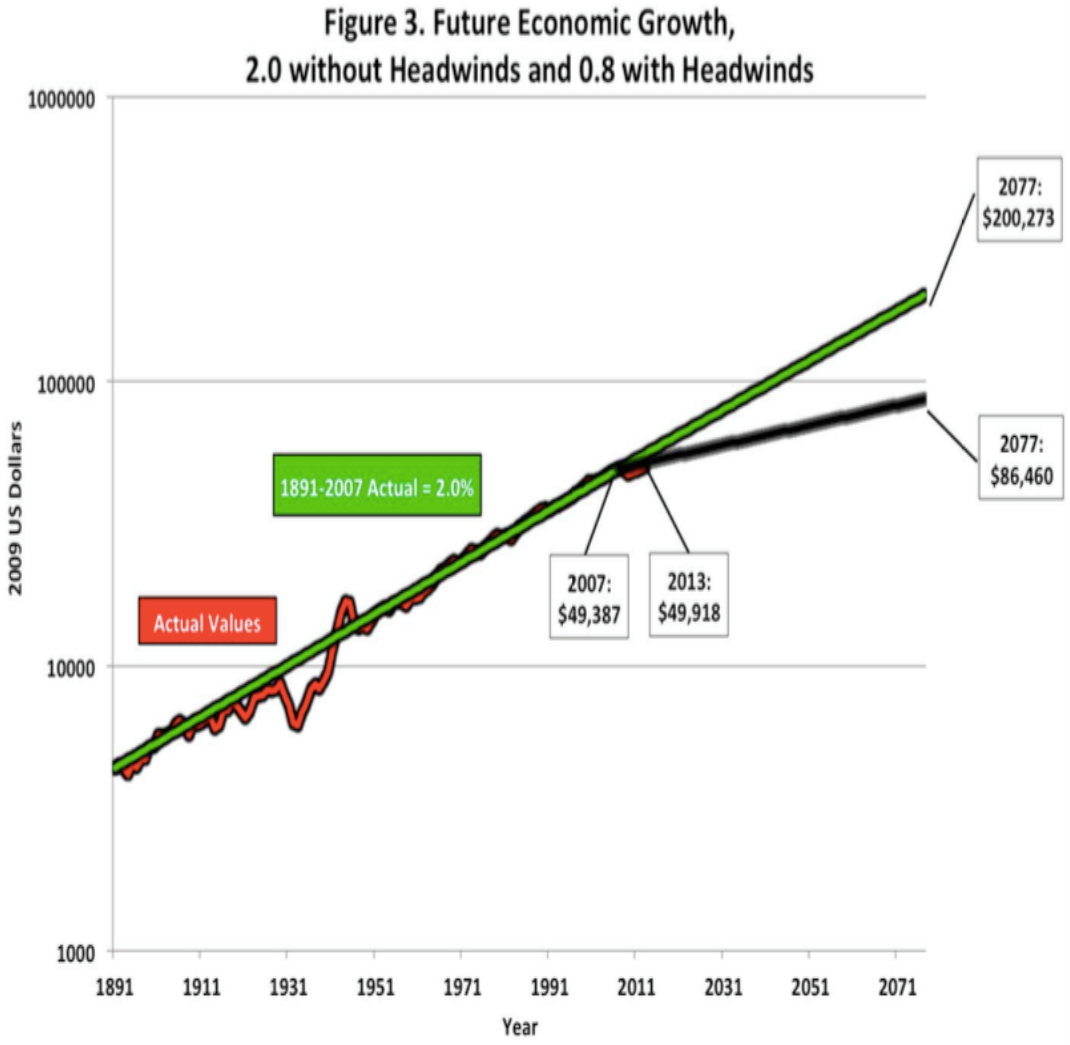
- Is 'the west' special between 800 and 1500?
  - Or is it just recovery from a Dark Age depression?

Bob Gordon: The Eighty Years After 1880

- In October, 1879, Thomas Edison created the first working electric light bulb…
- Between 1890 and 1930 the American household became fully "networked," replacing its previous isolation by five types of connections – electricity, gas, telephone, running water, and sewer pipes….
- Two months after Edison's electric light, Karl Benz achieved the first reliable and workable internal combustion engine…
- An Englishman named David Edward Hughes succeeded in sending a wireless signal several hundred meters in London almost two decades before Marconi won his earliest wireless patents
- At least three aspects of the Second Industrial Revolution have received less attention than they deserve… the multi-dimensional nature… everything happened all at once…. economic progress through 1972 mainly consisted of consolidating the incomplete aspects of IR #2 across many subsidiary and complementary inventions….
- Two criteria help to capture the uniqueness of IR#2. First, something cannot be more than 100 percent…. The second … some indicators cannot go below zero…

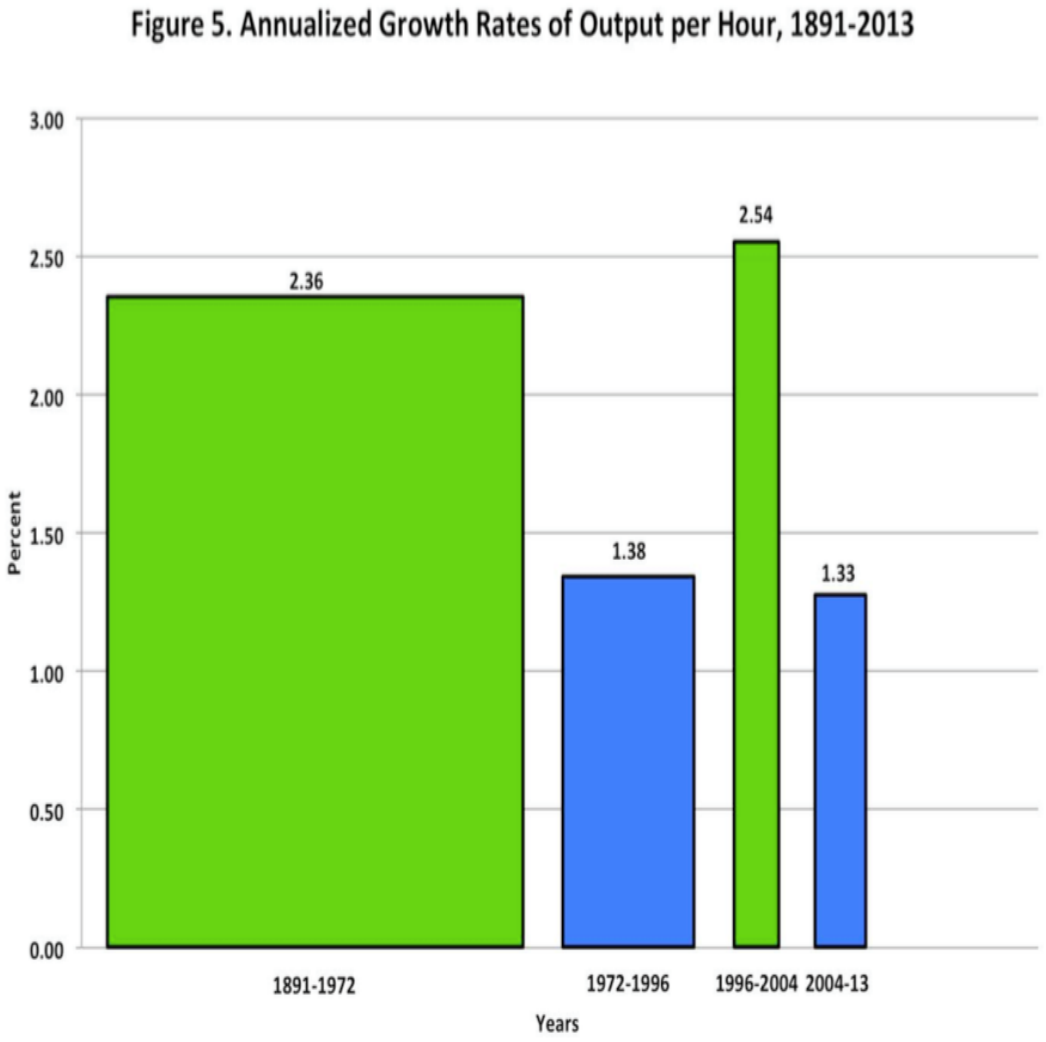
Bob Gordon: Power and Matter Manipulation and Flush Toilets

- Modern Economic Growth ain't going to continue
- It's really all about:
  - Nonhuman combustion-based energy sources
  - Use of energy and automatic machinery for matter manipulation
  - Flush toilets
  - Everything else that is important is subject to Baumol's disease
- The Trachtenberg/Nordhaus counter…
- The Varian counter…



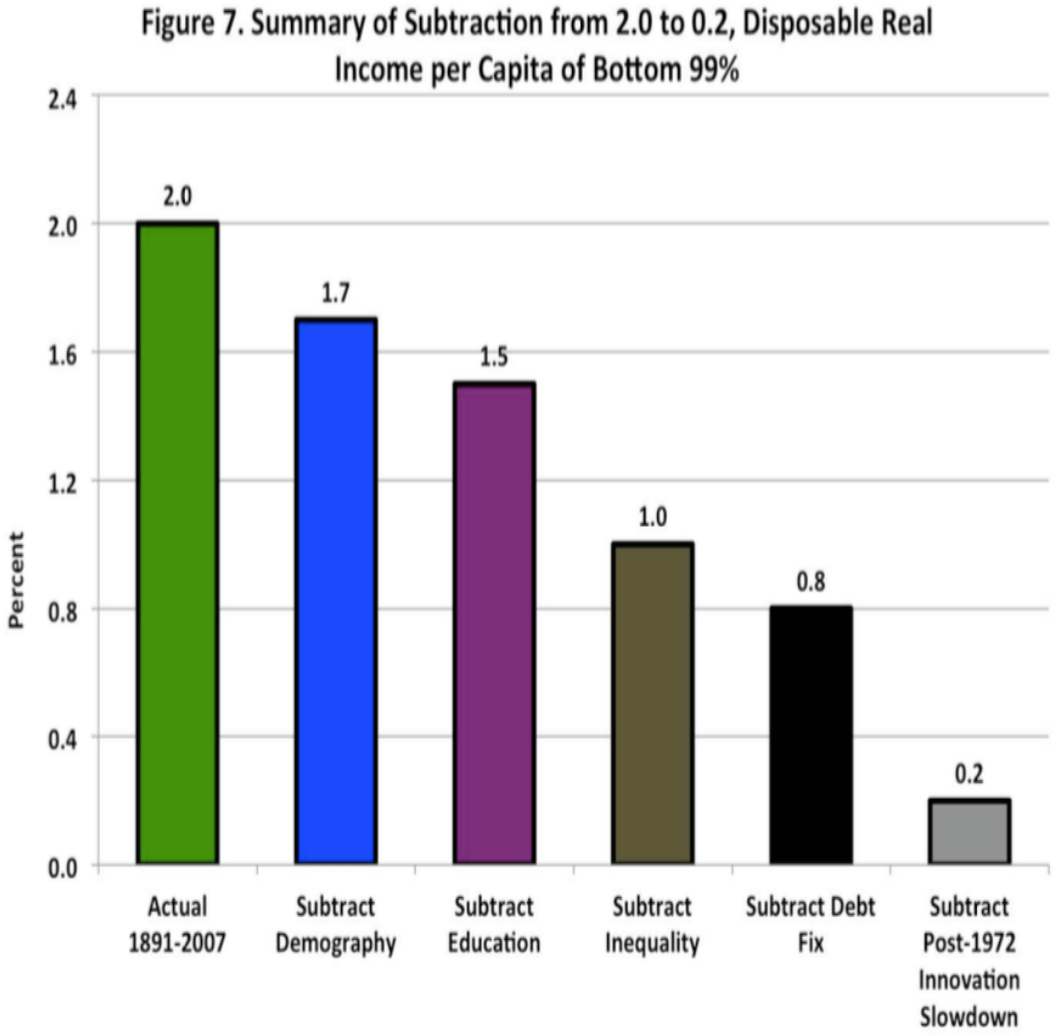
Bob Gordon: 1996-2004 a Flash in the Pan

- Modern Economic Growth ain't going to continue at its 1890-1972 pace
- In what ways is 2004-13 unrepresentative of the future?
- How would we figure out whether 1996-2004 or 1972-1996 is more likely going forward?



Bob Gordon: "Headwinds"

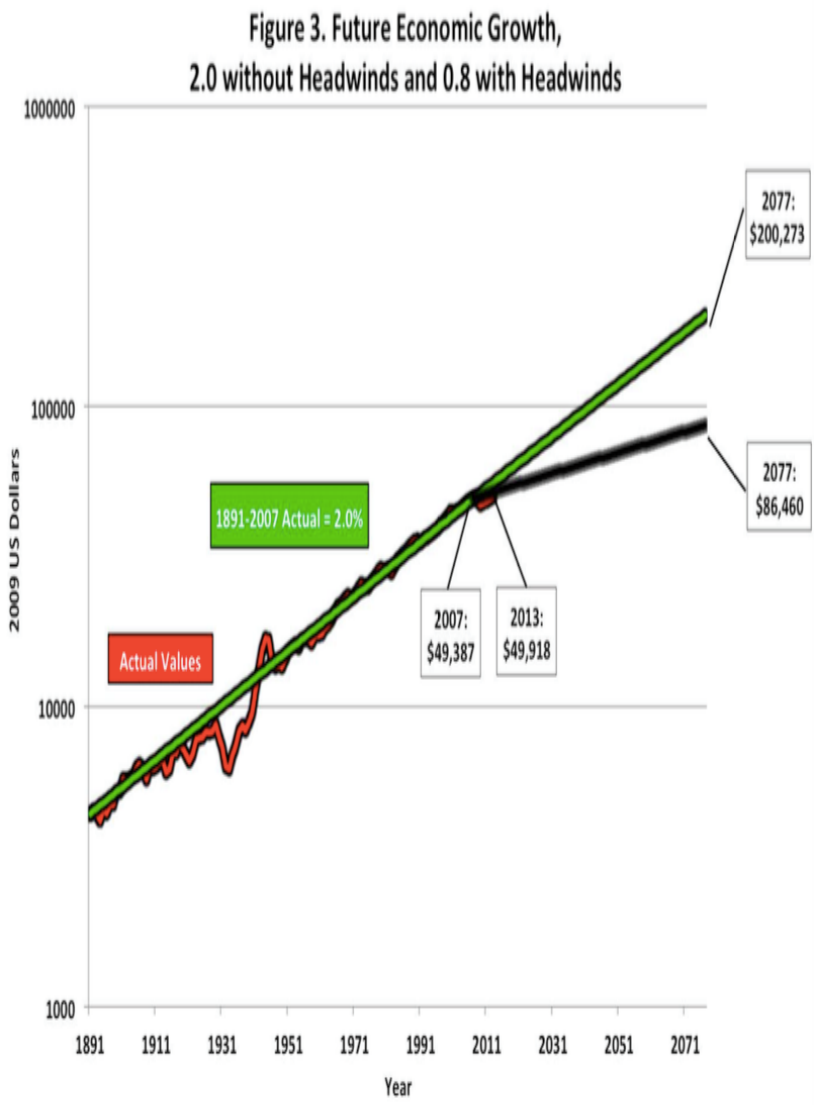
- Modern Economic Growth ain't going to continue at its 1890-1972 pace
- Demography yes…
- But education, inequality, "debt fix"?
- Gordon is greatly widening his critique beyond the uniqueness of IR#2



Bob Gordon: The Next Forty Years

- As we peer out into the future, the achievements of the past 40 years set a hurdle that is dauntingly high.
- The achievements that must be matched for importance in the next four decades include:
  - Memory typewriters, the personal computer, word-processing and spreadsheets
  - Bar-code scanning, ATM banking, cable and satellite TV
  - Internet, e-mail, web browsing, e-commerce
  - Google, Amazon, Wikipedia, Linked-In, Facebook
  - Mobile phones, smart phones, ipads
  - CDs, DVDs, i-tunes, Netflix, movie streaming
  - Airline reservation systems, supply-chain monitoring systems, electronic library catalogs
- What is in store for the next 40 years?

Questions About Gordon



Assignment Next Time: Unfreedom

What relevance and use does a work like Karl Marx and Friedrich Engels (1848), "Manifesto of the Communist Party" have to twenty-first century economists today?

Readings:

- Karl Marx and Friedrich Engels (1848): *Manifesto of the Communist Party* <http://www.marxists.org/archive/marx/works/1848/communist-manifesto/>
- Stanley Engerman and Kenneth Sokoloff (1994): *Factor Endowments, Institution*s and Differential Paths of Development among New World Economies <http://papers.nber.org/papers/h0066>
- Nathan Nunn (2008): *The Long-Term Effects of Africa's Slave Trades* <http://www.jstor.org/stable/pdfplus/25098896.pdf>

Catch Our Breath…

- Ask a couple of questions?
- Make a couple of comments?
- Any more readings to recommend?

Notes…

Reading Thompson

Peter Thompson (2001): How Much Did the Liberty Shipbuilders Learn? New Evidence for an Old Case Study <http://www.jstor.org/stable/pdfplus/10.1086/318605.pdf>:

- "The inclusion of the capital investment data diminishes the importance of learning. Without capital data, a ceteris paribus doubling of cumulative output is estimated to increase monthly output by 41 percent; the inclusion of capital reduces this estimate to about 22 percent…"
- "Quality…productivity mismeasurement… induces mismeasurement equivalent to only about 5 percent of observed productivity growth…"

Emergency Shipbuilding Program

- Liberty ship, an all-welded cargo ship with a displacement of 7,000 tons
- 16 U.S. shipyards delivered a total of 2,699 ships
  - A substantial portion of ship construction undertaken "off the ways"
  - 600,000 feet of welded joints
    - Welding labor accounted for about one-third of direct labor
    - Lots of new welders…
- A cadre, and—some—managers with experience. Otherwise…

Data: Labor

- 1,000,000 hours per ship in the middle of 1941…
- Falling to 300,000-700,000 hours pe r ship by the middle of 1943
- And there it plateaus
- What kind of production function would one want to fit here?

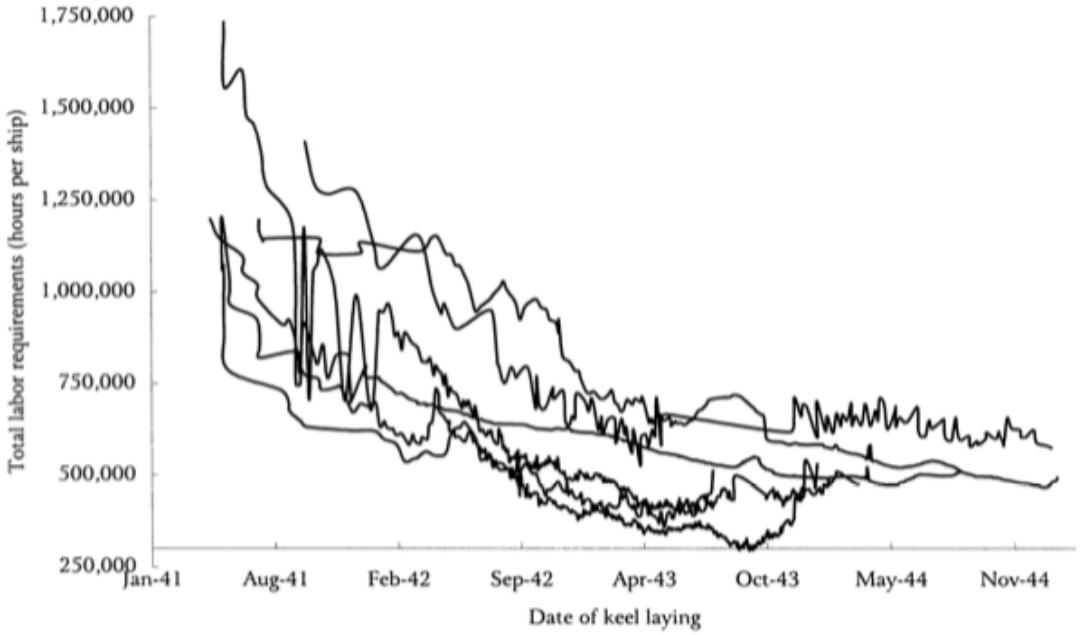


FIG. 1.—Standard Liberty ships labor productivity, six yards. The six yards are those for which capital data are available and that form the focus of study in this paper. See Searle (1945), Lane (1951), or Lucas (1993) for graphs of other yards. All ships delivered incomplete or modified are excluded.

$$\ln y_{it} = A_i + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln E_{it} + \epsilon_{it},$$

Data: Time

- Time—sequencing of production—is also an input into the production process
- Ships built in a short time are using capital very intensively indeed…
  - Learning how to use capital more intensively?
  - Diseconomizing on labor so that you can use the capital more intensively?

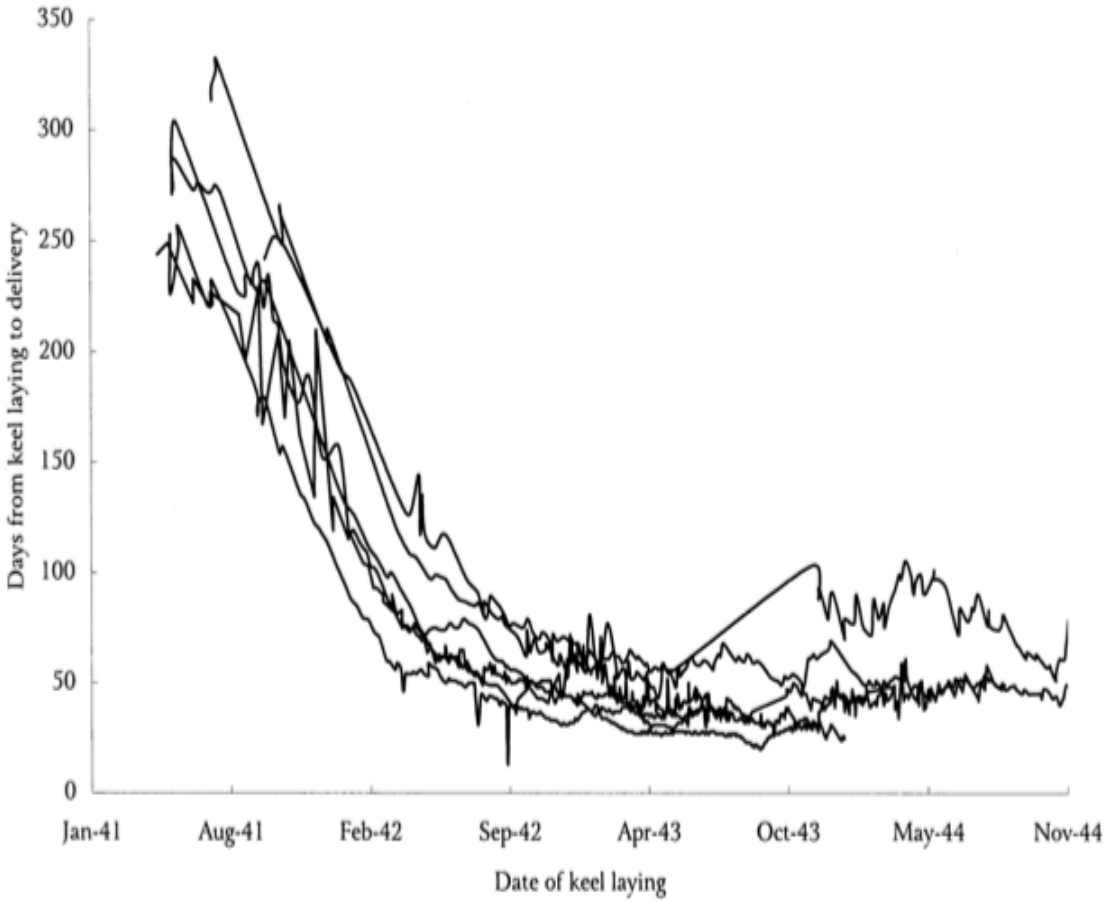


FIG. 2. —Standard Liberty ships production speed, six yards (see note to fig. 1)

Results

- 0.291…
- “Cumulative capital investment and experience are highly correlated, so that separating their effects reliably is difficult…”
- “It does seem reasonable to draw one conclusion from the Liberty ship program that is likely to resonate elsewhere: in a case study that is widely viewed as one of the cleanest examples of learning by doing on record, the real causes of productivity growth have turned out to be more complex and more diverse than economists have long believed to be the case…”
- WTF?!

TABLE 2
SURE Production Function Estimates (Experience Proxy: Cumulative Output)

	Rapping	Argote et al.	Dependent Variable: Log Monthly Output in Ship Equivalents			
	(1)	(2)	(3)	(4)	(5)	(6)
Log experience (cumulative output)	.110 (.013)	.44 (.03)	.493 (.025)	.481 (.027)	.291 (.045)	.263 (.037)
Log authorized ways	.293 (.096)	1.15 (.05)	…	…	…	…
Log operating ways	…	…	…	.274 (.236)	…	…
Log capital, K_{it}	…	…	…	…	.743 (.180)	.780 (.154)
Capacity utilization weight, $w_{it} = (6 + S_{it})/7$	…	…	…	…	…	.780 (.154)
Log labor hours	1.11 (.032)	.18 (.04)	.414 (.061)	.422 (.061)	.414 (.057)	.253 (.088)
Wald tests (p-values):						
Col. 3	…	…	…	.656	.000	.000
Col. 4	…	…	…	…	.000	.000
Adjusted R^2	.967	.990	.925	.922	.919	.711
Observations	48	337	182	182	182	149

Note.—Standard errors are in parentheses. Col. 1 reports coefficients from regression 6 in Rapping (1965, table 1). Rapping's regression 6 produced his lowest point estimate for the coefficient on experience, but the specification is closest to that used in the remaining columns of the table. Col. 2 reports coefficients from col. 2 of Argote et al. (1990, table 1). Regressions in cols. 3–6 include yard fixed effects and yard-specific AR(3) errors. Wald tests are tests that the coefficient on experience is the same as the point estimate in cols. 3 and 4. In col. 6 the coefficients on capital and the capacity utilization weights are restricted to be equal. Because total sample R^2 measures can mislead in pooled data, the adjusted R^2's in cols. 3–6 are the *lowest* of six yard-specific coefficients of determination. Total-sample coefficients of determination were all in excess of 0.92.