Markets for New Technology

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February 16, 2017

Smith Was Pessimistic About Future of Market Systems

Deadening effects of division of labor

Capital accumulation retarded by declining profits

Wages driven down to subsistence level

Enriched lazy landlords not an engine of progress

Did not foresee technical progress

Technological Advances of 1st Industrial Revolution

1712	steam engine	Thomas Newcomen
1764	spinning jenny	James Hargreaves
1770's	improved steam engine	James Watt
1780's	power loom	Edmund Cartwright
Early 18th	coke-fired furnace	Abraham Darby
Early 18th	steamboat	Robert Fulton
Early 18th	steam locomotive	Richard Trevithick
1820	road surface	John McAdam
1837	telegraph	William Cooke, Charles Wheatstone
1850's	mass production of steel	Henry Bessemer
1866	telegraph cable laid across Atlantic	

Technological Advances of 2nd Industrial Revolution 1870-1914

Gas and water supply

Sewage systems

Electrification

Telegraph, telephone, radio

Railroads

Internal combustion engine and automobile

Production line

Technological Advances of 3rd Industrial Revolution? 1940-??

Television

Jet air travel

Transistors and semiconductors

Space exploration

Satellite and cellular communications

Large-scale computers

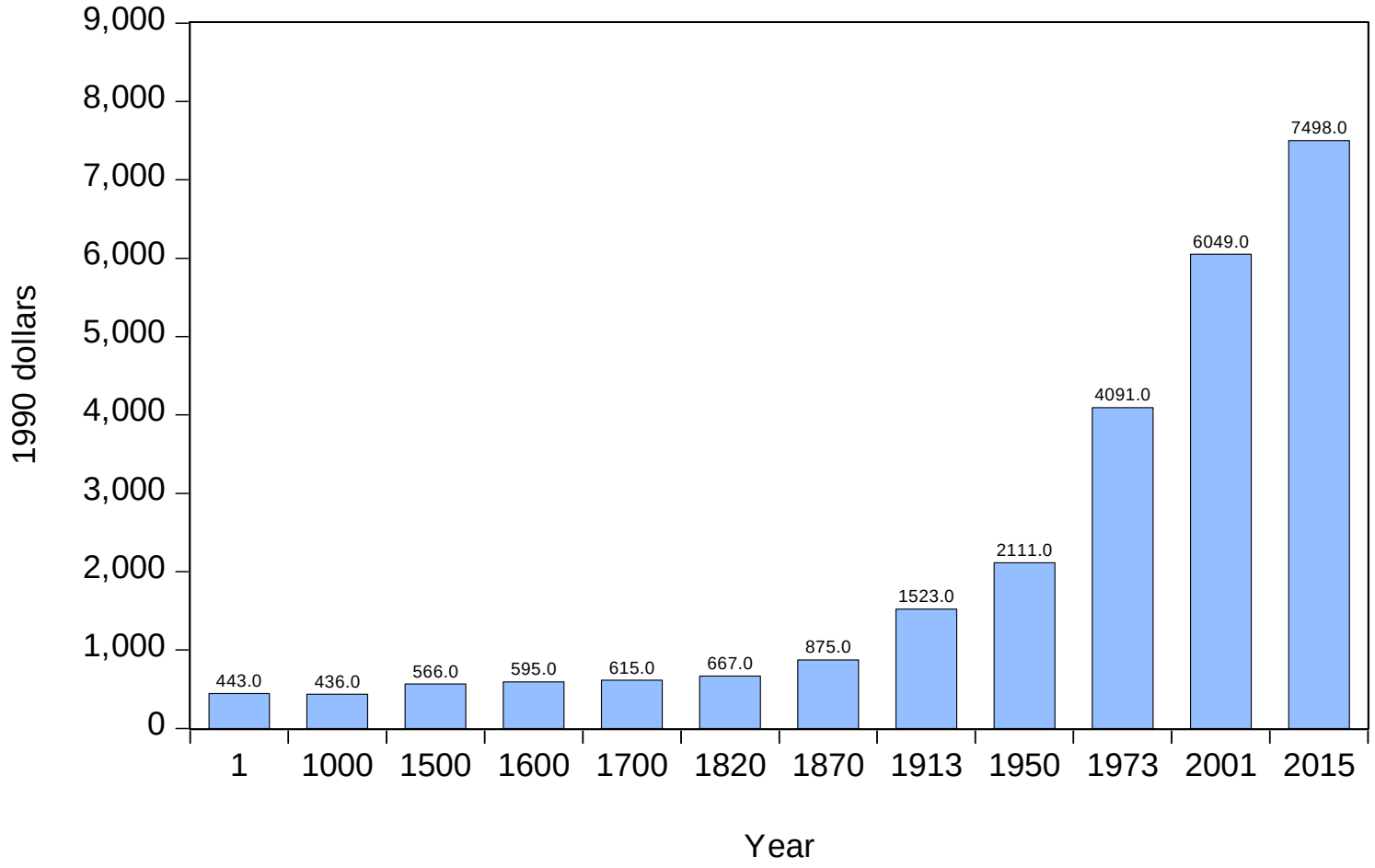
Personal computers

Genetic engineering

AI and robotics

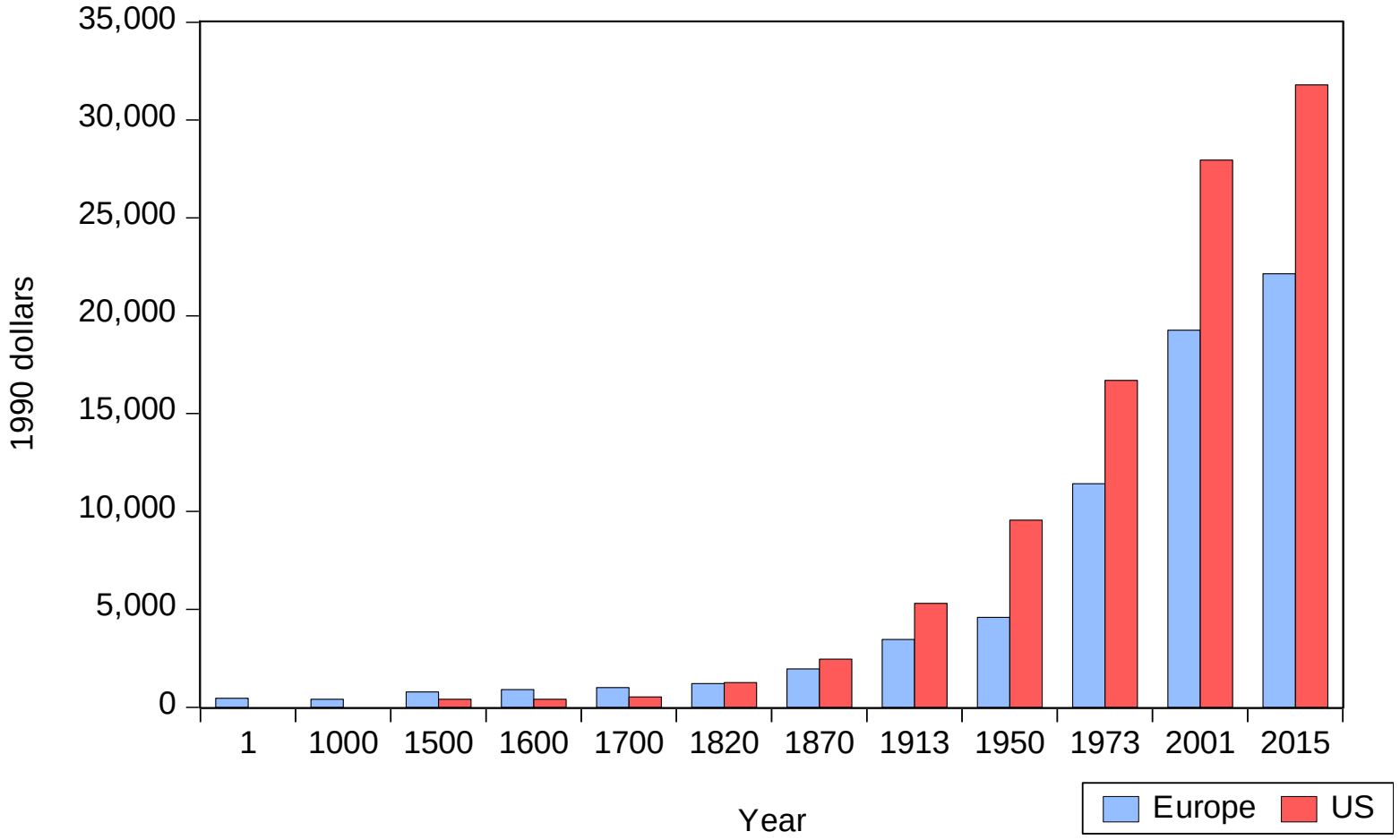
World Per Capita GDP, 1-2015

1990 dollars



Sources: A. Maddison, The World Economy: Historical Statistics, OECD, 2003;
2015 estimated using World Bank data

European and US Per Capita GDP, 1-2015



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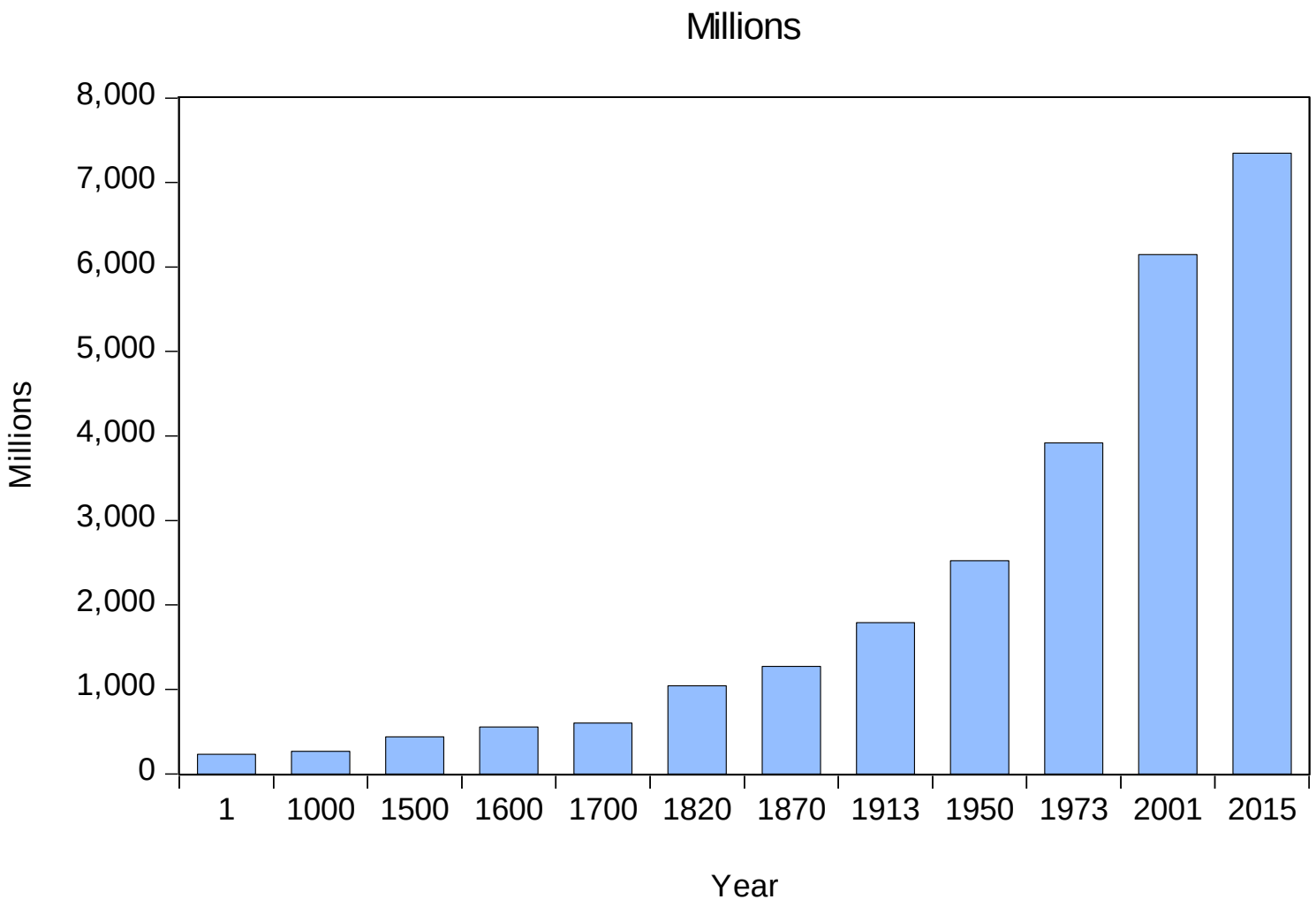
World Population,1-2015



Source: A. Maddison, The World Economy: Historical Statistics, OECD, 2003

Rate of Growth of Per Capita GDP, 1-2015										
Average annual rate (%)										
		Time period								
		1	1000	1500	1820	1870	1913	1950	1973	2001
		-1000	-1500	-1820	-1870	-1913	-1950	-1973	-2001	-2015
World		0.00	0.05	0.05	0.54	1.30	0.88	2.92	1.41	1.55
Europe		-0.01	0.13	0.14	0.98	1.33	0.76	4.05	1.88	1.00
US				0.36	1.34	1.82	1.61	2.45	1.86	0.93
Japan		0.01	0.03	0.09	0.19	1.48	0.88	8.06	2.14	0.77
China		0.00	0.06	0.00	-0.25	0.10	-0.62	2.86	5.32	9.07
Latin America		0.00	0.01	0.16	-0.03	1.82	1.43	2.58	0.91	1.62
Africa		0.00	-0.01	0.00	0.35	0.57	0.92	2.00	0.19	2.34
Sources: A. Maddison, The World Economy: Historical Statistics, OECD, 2003;										
	2001-2015 estimated using World Bank data									

Decomposing GDP Per Capita

$$\frac{GDP}{N} = \frac{GDP}{H} \times \frac{H}{E} \times \frac{E}{N}$$

GDP Per Capita = GDP Per Hour Worked

X Hours Worked Per Employee

X Ratio of Employment of Population

Note: GDP Per Hour Worked is usual measure of “Labor Productivity”

Decomposing GDP Per Capita

$$\frac{GDP}{N} = \frac{GDP}{H} \times \frac{H}{E} \times \frac{E}{N}$$

Hours Worked Per Employee falls over time

Ratio of Employment to Population also falls over time

Rising GDP Per Capita due to rising Labor Productivity

Why Did Labor Productivity Take Off After 1820?

- Development of markets
  - Enclosure of commons
  - Political consolidation and centralization
  - Decay of religious spirit
  - Emergence of business infrastructure and tools
  - Rise of scientific curiosity and invention
- Industrial Revolutions

Sources of Labor Productivity Growth

Increases in capital intensity -- equipping workers with more capital

Improvements in labor quality – improving workers' education, health

Technical progress – using labor and capital more efficiently

- Specialization and division of labor
- Reallocating resources to their best use
- Better management
- New techniques and products

U.S. Labor Productivity Growth and Its Sources, 1948-2015							
Private Non-Farm Business Sector							
Average annual rate (%)							
		Time Period					
		1948	1973	1990	1995	2000	2007
		-1973	-1990	-1995	-2000	-2007	-2015
Labor productivity		2.9	1.4	1.6	2.9	2.6	1.2
Sources:							
Labor quality		0.2	0.2	0.5	0.2	0.2	0.3
Capital intensity		0.9	0.9	0.6	1.2	1.0	0.5
Technical progress		1.9	0.4	0.5	1.5	1.4	0.4
Source: Bureau of Labor Statistics							

Is the Productivity Slowdown Temporary or Permanent?

Can labor quality be improved at a higher rate?

Can technical progress be accelerated?

NO, Robert Gordon

The Rise and Fall of American Growth, 2016.

Great discoveries have already been made
Computers, internet had only temporary impact 1995-2007
Falling behind in education

YES, Erik Brynjolfsson and Andrew McAfee

The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies, 2014

Digital era is just beginning to have impact
Broad applications of AI and robotics
Traditional measure of GDP doesn't capture benefits
Digitization is a "recombinant technology"

Some Landmarks of the “Second Machine Age”

1958 Defense Advanced Research Projects Agency (DARPA) founded
- Internet
- Automated voice recognition and language translation
- GPS
- Stealth technology

2002 DARPA First Grand Challenge
- $1M prize to build autonomous vehicle (unclaimed)

2011 ImageNet Challenge
- Visual recognition contests annually

2011 IBM’s Watson beats two best humans in TV game, *Jeopardy!*

2014 DeepMind’s AlphaGo system defeats one of world’s champs in Go

2015 DARPA Robotics Challenge
- $3.5M for robots that can drive alone, walk through rubble, trip circuit breakers, turn valves, climb stairs

Selected Indicators of Inventive Infrastructure and Activity

	Broadband subscribers (per 100) 2015	Internet users (per 100) 2015	High tech exports (% of manu-factured exports) 2015	Patent applications Residents 2014	Patent applications Non-res 2014	R&D exp (% of GDP) 2013	Researchers in R&D (per million) 2010	Scientific and tech journal articles 2013
Canada	36	89	14	4,198	31,283	1.69	4,649	57,797
China	19	50	26	801,135	127,042	2.01	903	401,435
France	41	85	27	14,500	2,033	2.24	3,868	72,555
Germany	37	88	17	48,154	17,811	2.83	4,078	101,074
Japan	30	93	17	265,959	60,030	3.47	5,153	103,377
Korea	40	90	27	164,073	46,219	4.15	5,380	58,844
Netherlands	42	93	20	2,294	288	1.96	3,229	30,412
UK	38	92	21	15,196	7,844	1.66	4,091	97,332
US	32	75	19	285,096	293,706	2.73	3,867	412,542

Source: World Bank, World Development Indicators, 2017

Maintaining an Environment Conducive to Technological Progress

Different policies for leader and laggers

Promote education for critical thinking

Establish research communities and centers

Encourage financial support of risky undertakings
- Venture capital, hedge funds, crowdfunding

Promote openness, decentralization, experimentation, mobility

Balance of big-business and small-scale efforts

Create competitions, prizes, awards for breakthroughs

Welcome the non-conformist, the outsider

END