III. Consequences and Causes of Economic Growth

A. Population growth

The tremendous increases in material wealth and living standards in the twentieth century have been accompanied by a three-fold multiplication in the human population of the world as well—the fastest rate of increase in human population ever, as best we can tell. This increase that has carried the human population of the world to levels that far outstrip those of previous centuries. Today there are more than six billion people alive on this earth: a century ago there were less than two billion.

1. The first billion people

Demographers guess that on the eve of the invention of agriculture—say, sometime around 10,000 B.C.—the hunting and gathering human population of the world was about five million. From then up until roughly the year one populations grew relatively swiftly, as civilizations based on agriculture and herding spread throughout the world as different groups learned the techniques of farming and livestock management from their neighbors. By the year one perhaps 250 million people lived on the earth.[1]

Thereafter populations grew more slowly. Arable land that could be used to grow crops using the technologies of the time was mostly occupied. When population expanded, it would run into sociological or biological limits: more people scratching a living from the same plot of land would

[1] See Massimo Livi-Bacci (1992), *The Concise History of World Population* (London: Blackwell: 0631204555); Carlo Cipolla (1962), *The Economic History of World Population* (London: Penguin: 0140205373). Worth reading on the long-run population history of humanity are Michael Kremer (1993), "Population Growth and Technological Change, One Million B.C. to 1990," *Quarterly Journal of Economics* 101:4 (August), pp. 681-716; Jared Diamond (1997), *Guns, Germs, and Steel: The Fates of Human Societies* (New York: Norton: 0393038912); Joel Cohen (1996), *How Many People Can the Earth Support?* (New York: W.W. Norton: 0393314952); Ronald Lee (1987), "Population Dynamics of Humans and Other Animals," *Demography* 24, pp. 443-65; Ronald Lee (1988), "Induced Population Growth and Induced Technological Progress," *Mathematical Population Studies* 1, pp. 265-88; T. Paul Schultz (1981), *Economics of Population* (Reading, MA: Addison-Wesley).

reduce nutrition, and deprive some women of the chance of conceiving; a lack of open farmsteads would keep young adults single and in their parents' households for an extended time, rather than forming households and having children of their own. Slow improvements in technology and investments in land-clearing would raise the pool of available natural resources to a population, fertility would rise, and population would grow-until once again the population would begin to press against the sociological or biological limits given available technology, fertility would fall, and the episode of growth would come to an end. Between the year one and the year 1700 demographers guess that the population of the world grew from roughly 250 million to roughly 700 million.

Human Population

Date	Population (Millions)	Growth (Percent Per Year)
10000 B.C.	6	0.008%
1	252	0.037%
1000	253	0.000%
1500	461	0.120%
1750	771	0.206%
1900	1,634	0.501%
1950	2,530	0.874%
1990	5,292	1.845%

Source: Massimo Livi-Bacci[2]

After 1700 population growth began to accelerate. Some argue that it was due to improving climates: both Europe and China appear to see substantial population growth in the eighteenth century, and China certainly did not benefit from the waves of technological innovation and improvement that were beginning to sweep over Europe.[3] Others argue that the quadruple

[2] Massimo Livi-Bacci (1992), *The Concise History of World Population* (London: Blackwell: 0631204555). Also well worth reading are Carlo Cipolla (1962), *The Economic History of World Population* (London: Penguin: 0140205373); Joel Cohen (1996), *How Many People Can the Earth Support?* (New York: W.W. Norton: 0393314952); and T.R. Malthus (reprint 1985), *An Essay on the Principle of Population* (New York: Penguin: 014043206X).

[3] But judgments that the Chinese economy was technologically stagnant under the Ming and Ching dynasties must be tentative because of our limited knowledge of techniques and their diffusion at the level of the village and the farm. It is entirely possible that Chinese technology was improving steadily at the rice-paddy level even though not at the cannon-making or book-printing level. See Ken Pomeranz (1997), "A High Standard of Living in Pre-Industrial China?" (Irvine: U.C. Irvine).

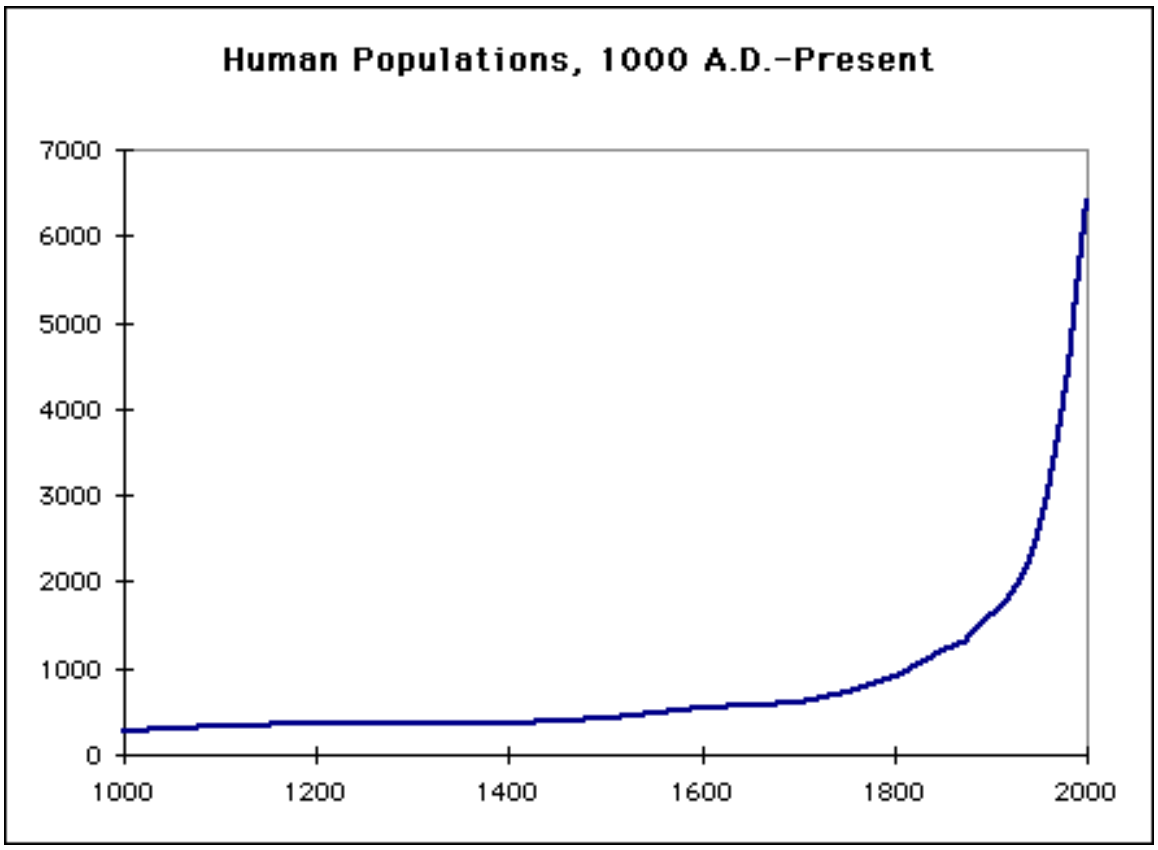
congruence of printing, religious doctrines generating higher literacy, technological innovation driven by constant wars between European nation-states, and expanded trade greatly multiplied Europe's command over its environment and banished the Malthusian forces that had previously swung into action to check population growth.[4]

2. The demographic transition

The eighteenth century appears to have seen human populations grow by perhaps fifty percent worldwide. The nineteenth century saw human population grow by some eighty percent. And—as modern technologies have diffused throughout the world—in the twentieth century human populations have tripled.

Before the twentieth century, the fastest-growing populations on the globe were almost invariably the richest populations on the globe. In the twentieth century things have been different: population growth in the richest countries has slowed down markedly. People are living longer than ever before, but also fewer children are being born, per couple of childbearing age, than ever before.

[4] See Eric Jones (1987), *The European Miracle* (0521280559).



This slowdown in fertility-based population growth to near-stasis in the world's richest countries is the second stage in what is called the *demographic transition.*[5] Thus the population of Europe has grown relatively slowly in the twentieth century—and are growing even more slowly today—even though it was by far the richest continent during most of the twentieth century.

The demographic transition is driven by rising income and wealth and the sociological changes that rising income and wealth set in motion. It has two components, or stages The first stage is one of greatly accelerated growth: a richer population has better nutrition, sees more opportunities, and receives better medical care. Thus both the biological and sociological checks to rapid population growth vanish. And population growth accelerates: life expectancy rises and more children are born.

The second stage comes when children cease to be a short-term addition to the economic resources of a household and become a short-term use of

[5] Demographic transition footnote.

economic resources: when—at least from the standpoint of five or ten years—having more children is no longer "investment" (in the number of people who will soon be able to help with odd jobs or the harvest, or the number of people who will be able to keep the household's textile spinning and weaving moving smoothly), but is instead more like "consumption". In relatively rich, urban populations most children are in school, and there is little that a pre-adolescent can do that would significantly increase household income in any case.[6]

Life Expectancy in the Demographic Transition

Country\ Year	*1750*	*1800*	*1850*	*1880*	*1900*	*1930*	*1950*	*1990*
England	36.9	37.3	40	43.3	48.2	60.8	69.2	74.5
France	27.9	33.9	39.8	42.1	47.4	56.7	66.5	76.1
Italy				35.4	42.8	54.9	65.5	75.9
Japan				35.1	37.7	45.9	59.1	78.5

Source: Massimo Livi-Bacci[7]

Thus mothers and fathers put more energy into sharply limiting the number of children in their households, and more energy into improving the quality of life and education for the children that they do have. Throughout the world, as countries have industrialized and urbanized, the pattern of rapid initial population growth followed by a sharp reduction in fertility and in the rate of population growth has repeated itself.

In country after country, birthrates have fallen from somewhere between 35 and 50 per thousand to somewhere near 10 per thousand. Death rates undergo a similar fall—faster in the beginning as the explosion of population that characterizes the first stage of the demographic transition takes hold. Life expectancy more than doubles. The age of the mother at the time of first childbirth usually rises. The age of the mother at the time of her *last* childbirth certainly falls—perhaps by as much as a decade. And the distribution of the population has evened out: no longer are populations made up of a mass of children, some adults, and a few old people. Instead the age distribution approaches a rough uniformity.

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[6] Cite to Becker, Murphy, and Tamura. Economists tend to be dogmatic about the demographic transition: that it is driven by economic factors, and that it inevitably swings into operation as economies pass through key levels of wealth and literacy. Other social scientists—especially demographers—are much less certain that they understand what is going on.

[7] Massimo Livi-Bacci (1992), *The Concise History of World Population* (London: Blackwell: 0631204555).

The first nation to go through the demographic transition was France.[8] The rest of the nations that now make up the industrial core of the world economy followed it. And today developing economies, like Mexico and China, are undergoing the same process.

Population grows extremely rapidly during the transition—the historical range is from a less-than-doubling for France to an apparent seven-fold multiple of population in Mexico's transition. But the period of rapid population growth has, in almost all cases to date, come to an end usually less than a century after the beginning of the steep fall in the death rate that marks the start of the transition.

Timing of the Demographic Transition for Selected Nations

Country	Beginning	End	Duration	Transition Population Multiplier
Sweden	1810	1960	150	3.83
Germany	1875	1965	90	2.11
Italy	1875	1965	90	2.26
Russia	1895	1965	70	2.05
France	1785	1970	185	1.62
China	1930	2000?	70?	2.46?
Taiwan	1920	1990	70	4.35
Mexico	1920	2000?	80?	7.02?

Source: Massimo Livi-Bacci[9]

[8] No one really understands why the demographic transition in France began when it did and proceeded as rapidly as it did. French (and Dutch) population growth drastically slowed down in the eighteenth and nineteenth centuries. Yet England—a little bit further advanced in terms of income per capita, but without French traditions of peasant smallholding—experienced its most rapid population growth just as the population of France ceased to grow. It is conventional to pin responsibility for the early demographic transition in France on the elimination of unused and potentially-arable land coupled with secure peasant ownership of land. Peasants are supposed to have then greatly diminished their own fertility in order to avoid having to divide up their plots of land among two or more sons, and thus impoverish their children. In England, by contrast, peasants had no security of land tenure: you were most likely to be a landless hired laborer. In this case why not have more children? They would be useful around the house from an early age, children are a joy, making children is a joy, and their prospects upon reaching adulthood would not be much worse for their being many of them.

To me this—narrowly economistic, land-tenure based—explanation of France's early demographic transition seems too simple and too neatly tied-up to be likely to be completely true. And it does not explain why Dutch population as well exhibited relative stagnation in the eighteenth century. But I do not have a better explanation at hand to offer.

[9] Massimo Livi-Bacci (1992), *The Concise History of World Population* (London: Blackwell: 0631204555).

3. Will Malthus return?[10]

Indeed, the demographic transition has progressed sufficiently far that the world appears to be past the time of maximum percentage population growth. In the late 1960s, the world population was growing at some 2.1 percent per year. Today it is growing somewhat more slowly, at some 1.7 percent per year.[11]

But how fast the rate of population growth will decline in the future, and what the trend of global population will be—that is anyone's guess. Some see a slowing-down of population growth as country after country undergoes its demographic transition, leading to a rough stabilization of human numbers in the range of 10 to 15 billion in the middle of the next century.

Others see catastrophe. They predict that the human species will run up against its natural resource constraints in short order. The human race will return to a population in which widespread famine and disease check human populations, and make up a normal part of human experience. Some even predict catastrophic die-offs of the human population.[12]

Indeed, some observers have been predicting the beginnings of widespread death from famine for thirty years—according to Paul Ehrlich's *The Population Bomb,* the first major famines and die-offs were supposed to hit the developing world in the early 1970s.[13] Yet so far nutritional levels

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[10] The reference is to T.R. Malthus's (1897) *Essay on the Principle of Population* (New York: Penguin: 014043206X). Malthus's argument was that in the long run living standards were set by a combination of (a) moral restraint created by religion which depressed the birthrate and (b) famine and poor nutrition-related disease. Hence technological advance could not in the long run alter human standards of living. Thus the liberals of his day—who undermined the authority of religion and thus of moral restraint—were working to humanity's detriment by lowering the long-run equilibrium standard of living.

[11] Joel E. Cohen (1996), *How Many People Can the Earth Support?* (New York: W.W. Norton: 0393314952).

[12] See Donella Meadows and Dennis Meadows, eds., *The Limits to Growth: A Report to the Club of Rome* (Universe Publishers: 087663918X). Their predictions of a catastrophic die-off hinge on their assumption that no steps can be taken to *constantly and continuously* shift production to a less resource-intensive pattern as resources become scarce. When this assumption is removed, their Malthusian model predicts a logistic-curve approach to a very densely populated earth at the biological limit of subsistence. See William Nordhaus (), "Lethal Model II," *Brookings Papers on Economic Activity.*

[13] Paul Ehrlich (1967), *The Population Bomb* (Buccaneer Books: 1568495870). It is not clear whether Ehrlich in the mid-1960s had no conception of the ability of better technology and more resources to boost

around the globe keep rising, food supply has more than kept pace with population growth, and there is no sign *yet* of a return of human populations to any "Malthusian" regime.

Whether declining rates of population growth will be the result of human choices in the presence of relative material abundance, or the result of a "Malthusian" apocalypse of war, famine, disease, and death is not yet clear to anyone. But there is reason to hope for the first: that the specter of Malthus will no longer haunt us.

B. The market economy

Why has the twentieth century been so different from all previous centuries in the pace of its economic growth?

One very partial answer is that the twentieth century has been blessed with *market* economies. Market economies have many powerful advantage over other ways of organizing economic activity—whether by redistribution within extended kin groups, reciprocal exchanges of goods for goods among people who know each other well, or large-scale government- or temple-mediated redistribution and storage. Market economies give manufacturers and traders every incentive to use resources most efficiently.[14]

They have the additional advantage of providing a "sunset" for relatively inefficient organizations: enterprises that are relatively inefficient cannot pay their bills, and vanish.[15] This automatic weeding-out of inefficient organizations that fail the test of the market is lacking where state

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agricultural productivity in the developing world, or whether he wished to sacrifice the accuracy of his forecast in order to gain more popular attention for the long-run danger.

[14] The classic source remains Adam Smith (1776), *An Inquiry into the Nature and Causes of the Wealth of Nations*.

[15] As economics evolves as a discipline it seems to be spending less and less of its attention on the price mechanism as a source of static allocative efficiency—as making sure that the marginal social benefit of the last unit produced is equal to its marginal social cost—and more and more on the price mechanism as a device for forcing the evolution of the population of organizations. Certainly the (static) allocative efficiency benefits of markets stressed in introductory textbooks cannot account for anything close to the extraordinary productive success of market economies. See William Baumol and Alan Blinder (1993) *Economics: Principles and Policy* 6th ed. (New York: Dryden Press: 0030974526).

enterprises draw on the general taxation or on the money-printing powers of the state.

1. The centrally-planned economy

How important has the fact that most economic life has been governed by the market in the twentieth century been? We are able to take a look at what production, distribution, and economic growth in the twentieth century might have been like in the absence of the market system by looking across what used to be the iron curtain, at how economic growth proceeded under the planned economic system of the Soviet Union.

In the Soviet Union the production and distribution of commodities was determined by vast bureaucracies. A complex structure of overlapping administrative hierarchies that gathered information, coordinated interactions, disseminated instructions, and monitored performance. The heads of the Communist Party stood at the top of the system, drawing information from and sending information to more than twenty ministerial committees, with such names as Gosplan, Gossnab, Gostroi, and Goskontrud. These ministerial committees in turn issued directives to and gathered information from more than fifty branch ministries composed of several hundred departments. At the base of the bureaucratic pyramid were the enterprises: 46,000 industrial enterprises, 50,000 state and collective farms; 47,000 construction enterprises, and 1,000,000 wholesale and retail trade enterprises.[16]

[Figure—Soviet propaganda plan-overfulfillment poster]

Planning began with directives from on high, that Gosplan used to produce numerical targets and priorities, and that were specified in increasing detail down the administrative hierarchy until they became specific targets for enterprises: your factory will produce five million ball bearings next year. Enterprises respond to these assignments by requesting machines, buildings, raw materials, workers, and other resources. Central authorities strive for maximal performance with threats of punishment and demotion,

[16] See Richard Ericson (1991), "The Classical Soviet-Type Economy," *Journal of Economic Perspectives* 5:4 (Fall 1991).

while subordinates plead their inability to perform their assigned tasks. The outcome is a comprehensive set of commands to all ministries that—in the eyes of the top, at least—involves a rough, tolerable balance between supplies and demands. Typically the result demands from each organization is a small percentage increase in what it is doing.

When it becomes impossible to do what was commanded because the plan is inconsistent or impossible, subordinates make critical choices on the spot in which they have every incentive to *appear* to fulfill the plan: a producer of ball-bearings will find itself driven to produce that assortment of bearing sizes and qualities which it can accomplish—whether or not fulfilling planned categories and numbers has any relation to social demand or to the needs of users. Thus tractor components are produced that do not fit with other components; buildings are built without the utility connections to make them habitable. Attempts by central planners to bring enterprise production into closer conformity with social needs generate additional inconsistencies, as central-planner interventions are made too quickly and made without accurate information.

[Figure: Magnitogorsk]

The resulting system lacked flexibility—no one has or can gain authority to solve problems—and lacked incentives: every incentive is to meet the plans and desires of superiors, and not to achieve beneficial economic consequences. The continued operation of the system depended in large part on human altruism. Humans are in fact altruistic: most social organizations are run to a large degree on gift-exchange relationships that depend on human sociability. But altruism alone is not enough to maintain a well-functioning social system.

Angus Maddison's estimates of GDP per capita in what was to be the Soviet Union relative to the United States suggest a social system that had very limited ability to catch up to the levels of material productivity found in the industrial core.[17] The figure below shows Maddison's estimates of Soviet

[17] See Angus Maddison (1995), *Monitoring the World Economy* (Paris: OECD: 9264145494). Maddison's estimates of GDP per capita back before World War I are derived by assuming that Russian economic growth was the same as Czechoslovak up until1860, and from Raymond Goldsmith (1961), "The Economic Growth of Czarist Russia, 1860-1913," *Economic Development and Cultural Change* (April) for the remainder of the pre-World War I period. His estimates of post-World War II estimates are the CIA's extensions and reworkings of Abram Bergson (1953), *Soviet National Income and Product in 1937*. For the communist period these estimates are best thought of as estimates of productive potential rather than of real incomes or consumer welfare: after all, the prices at which goods are valued and the process through which

productive potential—GDP per worker—as a fraction of the U.S. level and my estimates of real national incomes as a fraction of the U.S. level. The two differ drastically under communism: after all, communism is especially bad at translating productive potential into consumer welfare or household real incomes.[18]

Moreover, which estimate you prefer of the overall state of the Soviet economy relative to the American depends on who you are. If you are V.I. Lenin, J.V. Stalin, or L.I. Brezhnev, you almost surely prefer the higher "Maddison" series on the productive power and potential of the Soviet economy relative to the American one. The point is to build a powerful productive engine that can then be applied to advance the purposes of the regime—whether in projecting military power, in aiding governments favorable to the socialist camp around the world, in making impressive displays of technological power, or in gathering resources for a further leap into greater degrees of industrialization. From their standpoint the first wave of Soviet industrialization—the wave under Stalin, from 1928 to 1940 and then again in the repair of the awful devastation wreaked by the Nazis after World War II—was quite successful. It took a country that had perhaps one-fifth the per-capita productive power of the United States in 1928, and leaped forward to somewhere between one-third and two-fifths the per-capita productive power in a remarkably short time.

But if you are N.S. Krushchev or M.S. Gorbachev, then you have a very different evaluation of the success of the Soviet industrialization program. From the perspective of the standard of living of the rural population, the collectivization of agriculture did enormous damage. From the perspective of the standard of living of the urban population, the inability of the system to find rewards and incentives of sufficient subtlety to induce manufacturers to produce goods that consumers and investors would really want (not to mention the ideologically-forced starvation of the service sector as consisting of "unproductive labor"), the balance is considerably less favorable.

It is hard to believe that real incomes were in any sense much higher in the late 1930s than they had been at the end of the New Economic Policy—of market liberalization and the cultivation of small-scale

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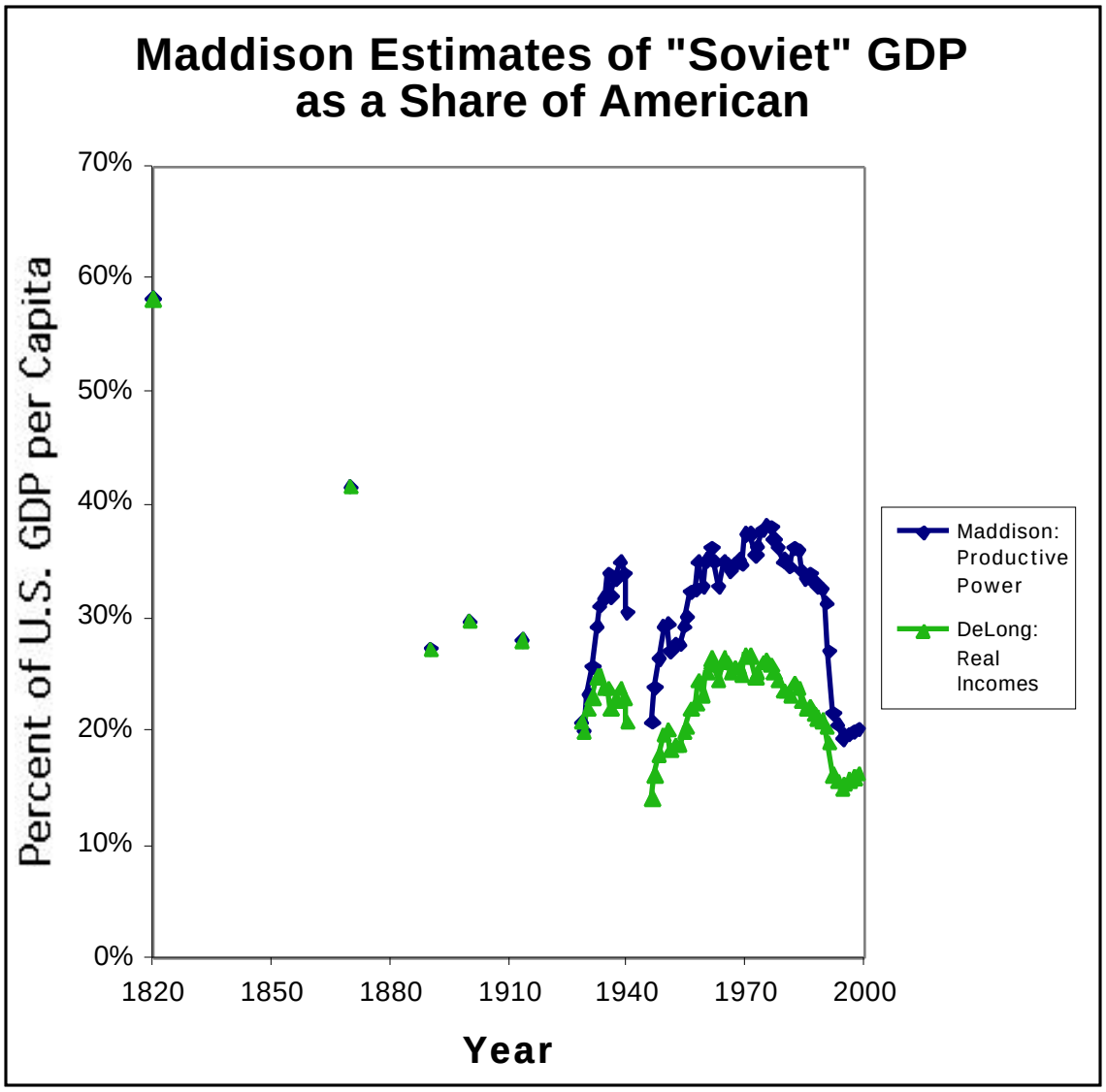
they are distributed under centrally-planned communism have very little to do with attempting to increase real incomes or consumer welfare.

[18] Needless to say, my estimates of the discount to be applied to estimated GDP to arrive at a measure of relative income levels—including the provision by the government of services such as defense—are extremely rough and back-of-the-envelope. I have made no attempt to calculate the substraction to material welfare engendered by the existence of the NKVD.

entrepreneurship—in the 1920s, or that Soviet industrialization after World War II carried the levels of real incomes in the U.S.S.R. even back to the proportion of American real incomes seen during the last days of the Czars.

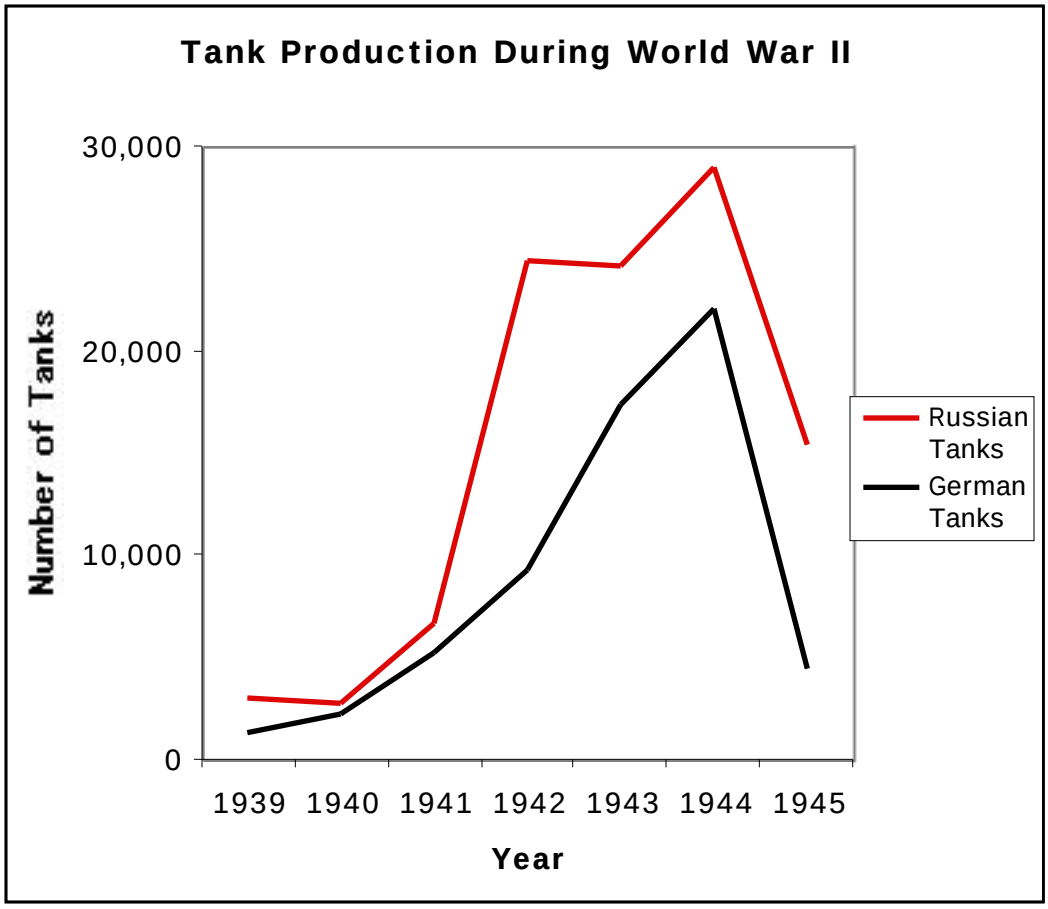
However, both series are valid, albeit for different purposes. It depends who you are, and what you are trying to achieve.



For the centrally-planned economies of the Soviet Union did function extremely effectively in certain, limited circumstances. When the task was to accomplish something where even the highest political authorities could see whether it had been accomplished or not, the system functioned: when the task was to build a subway for Moscow or a dam at Dnepropetrovsk, and when the party was willing to shoot people from chief engineers on down if the task was not accomplished, then Moscow got a subway and Dnepropetrovsk got a dam; when the task was to replicate something that existed elsewhere in the world, it could be replicated (although at enormously greater cost); when the consumers of an industry ran it, and had a blank check to use whatever methods and resources they wished to achieve the production of what they desired, then it could indeed be produced. The Soviet armed forces, with first claim on national resources and with the ability to send defaulters to Siberia or worse, got not state-of-the-art but functional equipment produced by the Soviet military production complex.

Perhaps the most important success of the Soviet productive apparatus was its military success during World War II, when the war production of Soviet industry enabled Russia's Red Army to break the back of the Nazi war machine.[19] With less than one-half of Germany's peacetime industrial capacity, with by 1942 less than one-fifth as much heavy industrial manufacturing capacity under its control as was held by the Nazis, Stalin's Communists managed to mobilize more resources to make more tanks and aircraft than Hitler's Nazis. It is possible (though unlikely) that the Soviet Union might have won World War II against Hitler if the U.S. and Britain had withdrawn from the war. It is not possible to conceive of how the U.S. and Britain would have beaten Hitler had Stalin's Russia withdrawn from World War II.

[19] Richard Overy (1997), *Why the Allies Won* (New York: W.W. Norton: 039331619X); Richard Overy and Peter Kaufman (1997), *Russia's War: Blood Upon the Snow* (New York: TV Books: 1575000512); David Glantz and Jonathan House (1995), *When Titans Clashed: How the Red Army Stopped Hitler* (Kansas City: University Press of Kansas: 070060717X).



But elsewhere? The Soviet Union singularly failed to produce quality consumer goods, or a varied crop of foodstuffs, or habitable apartments. As Richard Ericson assessed the harvest of seventy years of Soviet rule, it left the Communists' successors with:

> over sixty years where building physical capital and institutions has been largely an arbitrary, willful political act, independent of economic considerations. The result is a capital stock that is massively obsolete, abuse and destruction of the resource base, and an environmental poisoning unmatched in history. Most Soviet steel output uses a technology all but abandoned by the rest of the world. The bulk of investment goes to the backlog of unfinished, and never to be finished, construction. New industrial facilities that take less than two years to build in the rest of the world remain under construction for over fifteen years. Vast amounts of expensive imported equipment rusts at ports, rail sidings, and

> construction sites. Large oil reserves have been rendered inaccessible by use of technologies allowing rapid and easy meeting of quotas. The entire Aral Sea area of central Asia has been poisoned, the sea itself reduced to a salinated cesspool and the agriculture around it ruined by excessive use of chemicals, all in pursuit of the plan...[20]

3. Advantages of the market

How does a market system do a better job? First, it imposes a reality check on every organization—an organization that is relatively inefficient at producing will find its customers going elsewhere, and its revenues falling. It will soon go bankrupt and vanish. This "sunset" concentrates the minds of bosses and managers on figuring out how to produce more goods, more efficently.[21]

Second, it imposes a reality check on every line of business because products that are unsatisfactory to customers do not sell: there is no such thing in a market economy as "overfulfilling" your plan targets by producing something that is useless to all of your customers.

Third, the market possesses enormous flexibility: organizations and individuals can change their production patterns any time they choose, without seeking approval at all levels up to and including the highest levels of the national government. And organizations have every incentive to do so whenever market prices tell them that their resources could be more efficiently used producing a different mix of products.

Comparisons of the Soviet Union's economy, and of the economies of the other Communist regimes of Eastern Europe, with Western European patterns suggest that adoption of the market economy has the capacity to multiply economic prosperity by a factor of two to five.[22]

Looking back at history reinforces the lesson that market economies are good for prosperity. Previous episodes of mercantile capitalism—like Classical Athens around 400 B.C., Sung dynasty China around 1000 A.D.,

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[20] Richard Ericson (), "The Classical Soviet-Type Economy," *Journal of Economic Perspectives* .
[21] Thus an answer to Lenin, who had wondered how the trusts and monopolies of his day were different from socialized production. See Vladimir Lenin (1916), *Imperialism, the Highest Form of Capitalism* ().
[22] Cross iron curtain productivity comparisons.

Mediterranean Islam *circa* 1000, northern Italy around 1500, or Augustan Britain around 1750—have been among the brightest of the relatively few bright spots in human history. They have been richer than their neighbors, and they have seen wealth and enterprise spread and increase.[23]

But until this century there has been no episode of "capitalism," no example of a market economy that has generated anything like the explosion of wealth that we have seen. The twentieth century has been unique, and has seen wealth grow much more rapidly than can be accounted for by reference to the incentives provided by and the Harberger triangles eliminated by a market economy.[24]

So at least two additional factors have been very necessary to the economic miracle of the twentieth century: first, political democracy; second, technological density.

C. Additional causes of growth

1. Political democracy

Before our century, a productive mercantile economy was a goose that laid golden eggs. But from a historical perspective, a golden goose is a short-lived beast. The ruling prince was always subject to the temptation to squeeze the goose a little tighter, either to pay for a slightly greater degree of courtly splendor or to pay for a slightly higher military effort on whatever was the current active conquest frontier.

In fact, history is littered with the corpses of golden geese.[25]

One of the oldest themes in economics is the incompatibility of despotism and development. Economies in which security of property is

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[23] See Moses I. Finley (), *The Ancient Economy* (); Carlo Cipolla (), *Before the Industrial Revolution* (); John Brewer (1997), *The Pleasures of the Imagination* ().

[24] See James Hines (1999), "Three Sides of the Harberger Triangle," *Journal of Economic Perspectives* ().

[25] For some examples see Mancur Olson (196?), *The Logic of Collective Action* (); William Baumol (), "Entrepreneurship," Wole Soyinka (1996), *The Open Sore of a Continent* (); J. Bradford De Long and Andrei Shleifer (1993), "Princes and Merchants: City Growth before the Industrial Revolution," *Journal of Law and Economics* ; Gianfranco Poggi (1978), *The Development of the Modern State* (Palo Alto, CA: Stanford University Press).

lacking—because of either the possibility of arrest, ruin, or execution at the command of the ruling prince, or the possibility of ruinous taxation—experience relative stagnation. By contrast, economies in which property is secure—either because of strong constitutional restrictions on the government's power, or because the ruling class is itself a mercantile, property-owning, entrepreneurial class—should prosper and grow. Even in the eighteenth century, both Adam Smith and Montesquieu remarked on the correlation between constitutional republican rule and economic growth, and between despotism and economic decline.[26]

And a transition from a mercantile republican to a despotic or a dictatorial regime usually meant that the best days of the local economy were past—that economic decline was on the way as higher and higher taxes and greater and greater exactions to achieve whatever were the current goals of the rulers disrupted the mercantile economy.

Successful democracy changes the calculus. Once people have gotten it into their heads that legitimate governmental authority comes not because God has anointed the king or through inheritance, it becomes hard to maintain a government that does not have popular support. At the very least, regular plebiscites are necessary to demonstrate that the current bunch of thugs-with-guns holds power by the will of the people. If not, then other bunches of thugs-with-guns will be tempted to stage coups, or the government will fall because mass discontent and demonstrations undermines the loyalty of the army: think of the fall of the Shah of Iran in 1979, of President Ferdinand Marcos of the Philippines in 1986, of the Argentine junta that attempted to imprison Juan Peron in 1945, of Erich Honeker's Communist regime in East Germany in 1989, or of Suharto's regime in Indonesia in 1998.[27] In the later stages of the twentieth century, especially, even governments that are not elected by the people are still routinely overthrown by popular discontent following economic failure.

Hence courtly splendor and an overmighty military budget become of less interest and less urgency to rulers—even to non-democratic rulers. Keeping real wages rising, employment high, and profits growing becomes the principal aim of governments. For political parties that are either

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[26] Adam Smith (1776), *An Inquiry into the Nature and Causes of the Wealth of Nations* (); Charles Secondat, Baron de Brede et de Montesquieu (), *The Spirit of the Laws* ().

[27] Suharto fell in spite of the fact that under his thirty-three year dictatorship Indonesian output per worker hamore than quadrupled. The popular view when the Crash of 1997 came seemed to be: "What have you done for me lately?" But Suharto and his regime had also killed somewhere upwards of 700,000 people, making it onto the list of the twenty most genocidal regimes of this century. Surely his departure is likely to be a good thing.

unlucky to catch an unfavorable wave of the business cycle[28] or unskillful enough to disrupt economic growth are likely to vanish rapidly. Economic growth becomes an aim of government policy in itself, rather than a way station on the way to a larger military budget.

This is not to say that governments know how to achieve economic prosperity. It is possible to question whether the net impact of government attempts to boost output and employment in this century has been positive. But before the coming of modern democracy, government policy had a substantial bias *against* economic growth.

Some—in recent years mostly apologists for semi-authoritarian semi- or un-elected East Asian rulers of rapidly-growing economies—have argued that democracies are subject to "indiscipline": civil disorder, or cycles of tax-your-enemies and reward-your-political-friends. By contrast, they argue, a benevolent dictator has every inclination to take the long view, for his security of tenure and the power of his successors are closely linked to rapid economic growth.[29]

But there is a problem with this argument. There is no such thing as a "secure" dictatorship. There is no such thing as an authoritarian ruler who can afford to take the long view.

There never was.

Consider, as an example, the monarchy of England, the strongest in Europe for the five hundred years 1000-1500, and still strong up until the Glorious Revolution of 1688. Queen Elizabeth I Tudor executed her legal heir. King Richard I Plantagenet "Lion-Heart" found that his younger brother had bribed the Duke of Austria to imprison him. 18 out of 31 monarchs had something go seriously awry with the succession before or upon their death. Only one time in five did the English throne pass peacefully down to the legitimate second-generation heir of any monarch. Any one dictator can

[28] See Richard Nixon (1964), *Six Crises* (). Richard Nixon believed that the refusal by Dwight Eisenhower and his advisors to stimulate the economy in 1960 cost him the election. A substantial amount of statistical work finds a correlation between positive economic outcomes and the reelection chances of governments. See Ray Fair (1996), " ," *Journal of Economic Perspectives*

[29] In our day this argument appears as an invocation of the superiority of "Asian values" (or used to so appear before the 1997-1998 Asian financial crisis. In past times this argument appeared as a liking for so-called "Enlightened Despotism," or as a preference for the ordered discipline of Sparta, or of the King of Macedon over the disorder of more-democratic Athens.

be "enlightened," and pro-development. The chance of a chain of such despotic rulers being benevolent is very small indeed.[30]

Bet on democracy as a co-requisite for successful economic development in the long run.[31]

2. Technological density

Even the conjunction of market economic organizations and political democracy is insufficient to account for the economic miracle of the twentieth century. Both of these factors are only tangentially related to the extraordinary explosion of technology—of scientific knowledge and its application to production in every day life—in this century. In order to achieve this century's revolutions in science and technology, we need "technological density" as well: research and development has to become an industry in itself, rather than an avocation of a few learned gentlemen reading papers before a Royal Society, to maintain the pace of invention and innovation that we now take for granted. Only the confluence of all three, market institutions, political democracy, and high technological density, could generate the economic revolutions of the twentieth century.

Hiero of Alexandria built the first steam engine roughly two thousand years ago.[32] An enclosed sphere on a vertical pole with two openings, one on the right side and one on the left, each pointing counterclockwise. Put some water in the sphere and put the apparatus over a fire. The water boils, the steam escapes through the jets, and the sphere begins to spin clockwise.

A pleasant toy.

It would be more than seventeen hundred years before the steam engine would be used to substitute for human or animal musclepower to boost production. Much pre-industrial technology seems similar: ideas that

[30] This argument is taken from J. Bradford DeLong and Andrei Shleifer (1993), "Princes and Merchants: City Growth Before the Industrial Revolution," *Journal of Law and Economics* 36. The record for successive reigns by enlightened despots is five: Nerva, Trajan, Hadrian, Antonius Pius, and Marcus Aurelius—the Antonine dynasty of the second century Roman Empire. See Edward Gibbon (), *The Decline and Fall of the Roman Empire* ().

[31] A reason to be relatively optimistic about the long-run economic development of India—and relatively pessimistic about the long-run economic development of China.

[32] Henry Hodges (1970), *Technology in the Ancient World* (New York: Random House: 0394448081).

contain the germ of powerful advances in human command over nature, but just the germ, and are never developed. There is technological progress in the ancient and the medieval world, but it takes place at a glacially slow pace. Medieval historians plot the hundreds of years that it takes the horse collar—so that the weight of whatever the horse is pulling rests on its shoulders, not its neck; thus the horse does not half-choke itself every time it tries to pull—to diffuse and become general across Europe. They plot the thousands of years that it takes the water wheel to become common, and the extraordinary lapses of time before simple improvements—like going from the "undershot" to the "overshot" wheel—are introduced.

And there are times of retrogression. Go to the Musee de Cluny in Paris and look at the crowns of the Visigoths, a tribe of barbarians that conquered and ruled what is now Spain for more than two centuries at the end of the Roman Empire and before the Muslim invasion of Iberia. Their crowns show pathetically poor workmanship: the Visigoths in 600 A.D. could not find any goldsmiths in Spain capable of doing work even one-tenth as competent as was routinely done in the Iberian city of New Carthage (Cartagena) 800 years before.

Some of the reasons for slow improvements in technology were cultural. Archimedes is reputed to have refused to write a handbook of engineering; Henry Hodges reports that the reason given was that "the work of an engineer... was ignoble and vulgar."

Some of the reasons for slow progress before the industrial revolution was a lack of people to think of new ideas—and a lack of ways for intellectual communities to form. Before the industrial revolution the growth of human populations' technological mastery—as proxied by the rate of growth of their populations—roughly paralleled their numbers.[33] Back when the human population was less than 100,000, population growth averaged less than one-tenth of a percent per year; by the time the human population reached a billion, population growth averaged half a percent per year. It is very tempting to conclude that a share of the history of technology can be accounted for by the principle that two heads are better than one: back before the industrial revolution higher populations meant higher growth rates because higher populations had greater *technological density* and thus a faster rate of technical progress.

Technological density depends on more than numbers. We today have

[33] See Michael Kremer (1993), "Population Growth and Technological Change," *Quarterly Journal of Economics* 108.

much more than the ten times the capability to invent and discover that the human race had five hundred years ago and that a simple count of human numbers would suggest. In broad historical perspective, there have been four upward leaps in technological density over the past ten thousand years that have greatly improved communication at any given level of population density: *writing*, *printing*, the development of the specialized vocabularies and procedures of modern *science*, and the long-distance *telecommunications revolutions* that make communication nearly instantaneous across the entire globe.[34]

Information about what human life was like before the invention of *writing* is—not surprisingly—scarce. That it transformed humanity's capability to remember and thus to build technological knowledge there can be no doubt. Sir Isaac Newton noted that "If I have seen further than other men, it is because I have stood on the shoulders of giants." And we remember what he said because he wrote and we can read. Such shoulder-standing is simply not possible without writing to make reliable communication across generations possible.

Printing—in the sense of Johann Gutenburg and movable type—is only some five hundred years old in Europe, and only some twelve hundred years old in China. The impact of printing on China (little impact: used for the mass distribution of some Buddhist texts, but for little else) should caution us against any narrow belief in technological determinism. Sir Francis Bacon, for example, noted that the three inventions of gunpowder, the compass, and printing had utterly transformed Europe.[35] Yet all three of these were known, indeed invented, in China. And they had not transformed China.

But in Europe the invention of printing had a profound effect on much of cultural, religious, and scientific development. Over the fifty years separating pre-Gutenberg times from the start of the sixteenth century, the cost of producing a book fell by a factor of several hundredfold: for the time and skilled labor that a monastic scribe would have taken to produce several manuscript copies of a work, a post-Gutenberg printer could (using a different kind of skilled labor) produce 1,000 copies.[36]

After Gutenberg the purchase of a book was a more significant decision than today, when buying a book consumes the money earned in 15 or 30

[34] See Elizabeth Eisenstein (), *The Printing Revolution in Early Modern Europe* () on the printing revolution—and the difference that it made for science, for the Renaissance, and for the Reformation.
[35] Sir Francis Bacon cite.
[36] Missing reference.

minutes of work by the average established member of the *literati*. Technical progress in book production has contributed to further tenfold or so since the immediate post-Gutenberg age; offsetting this is the fact that the average established member of the literati ranked considerably higher in the income scale in the sixteenth century than today; the representative book purchaser in the sixteenth century spent the equivalent of an hour or two's wages on a book.

[Figure: Gutenberg's bible]

Contrast this with the month or more's worth spent on creating and purchasing a pre-Gutenberg manuscript—overhead for maintaining the library and the scriptorium, the time of the copyist (and the requirement that the copyist be highly literate lest he corrupt the manuscript), and distribution of what was truly a one-of-a-kind product.

What difference did it make that the cost of production of the "unit of information" that was a book went from weeks or months of skilled labor time to hours of skilled labor time? For one thing, the seventeenth-century origin of modern science is unthinkable without the density of information exchange made possible by printing. It is no coincidence that Copernicus follows Gutenberg by less than a century.[37]

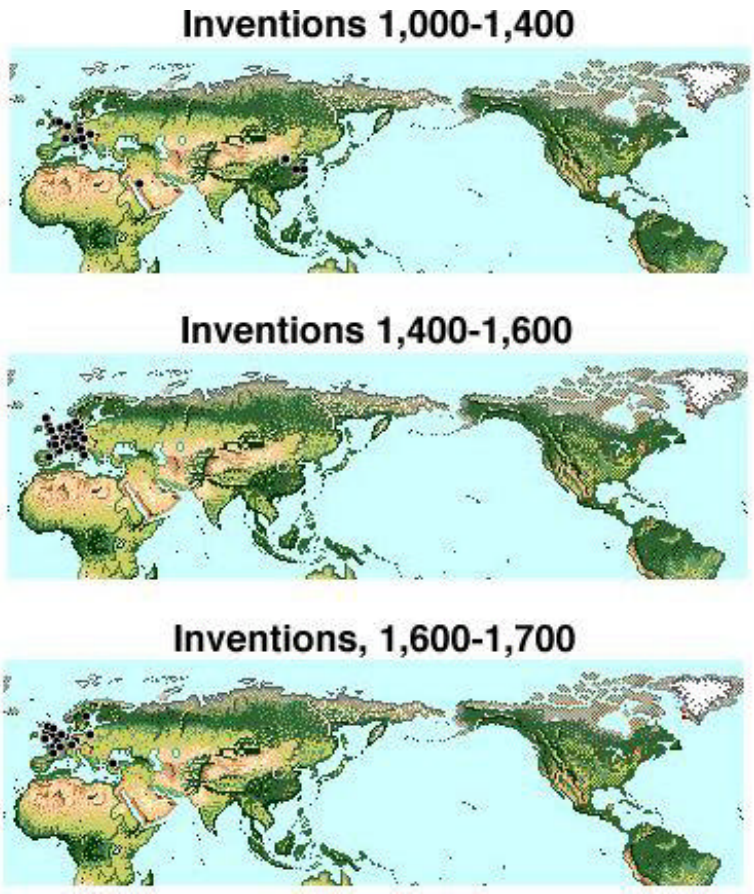
[Picture: early steam engine]

The process of economic growth was perhaps unstoppable after Galileo, and probably unstoppable after Newton. The success of each previous generation's scientists and engineers enlarged the pool of those willing to work on science and technology in the next generation. The printing press made the diffusion of work and knowledge across Europe cheap, easy, and rapid. The second half of the seventeenth century saw the invention of the pendulum clock, the pocket watch, the microscope, the vacuum pump (without which the steam engine was impossible)—and champagne. The first half of the eighteenth century saw the invention of the flying shuttle (which doubled weaving productivity) and the Newcomen "atmospheric" steam engine. The second half of the eighteenth century saw the invention of Arkwright's automatic spinning machine, of the improved Watt

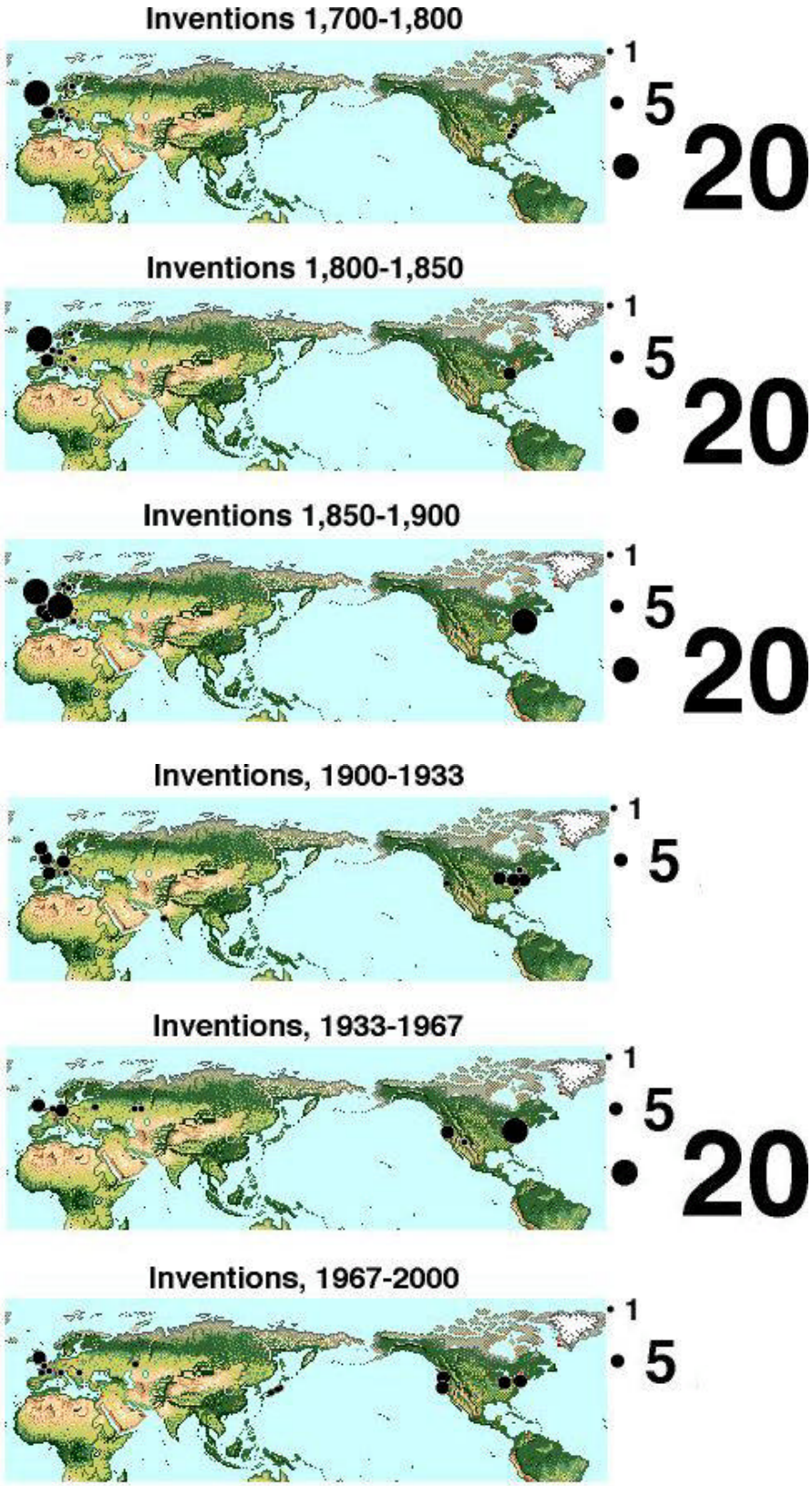
[37] I. Bernard Cohen on the scientific revolution.

"condenser" steam engine, the power loom, the cotton gin, the hot-air balloon, vaccination, and lithographic printing.

Perhaps the most impressive way to view the gathering pace of invention is to plot inventions over the past millennium: where they occurred on the globe, and when. The concentration of inventions in northwest Europe (in striking contrast to, say, the years between 500 and 1000, when the plurality of interesting inventions came from China); the extraordinary stepping-up of the pace of invention; and then the extension of the innovative core to include first North America and now Japan are very clear. The overwhelming impression is of a positive-feedback, increasing-returns-to-scale process that once it has past a critical initial value accelerates without pause. And to date there are no signs of a slowing of the process of invention and innovation.[38]



[38] See Paul Romer (1986), "Increasing Returns and Economic Growth," *Journal of Political Economy* ; Martin Weitzman (1998), "??," *Quarterly Journal of Economics* ; *Smithsonian Visual Timeline of Inventions* (New York: Dorling Kindersley).


Inventions 1,700-1,800
1
5
20
Inventions 1,800-1,850
1
5
20
Inventions 1,850-1,900
1
5
20
Inventions, 1900-1933
1
5
Inventions, 1933-1967
1
5
20
Inventions, 1967-2000
1
5

Some argue that cultural configurations played the key role in spurring the wave of innovation that turned into the flood of the industrial revolution. David Landes traces the "invention of invention" back to Judeo-Christian respect for manual labor; to the belief that nature was regular, predictable, and subordinate to humanity; and to the belief that time was linear and progressive, moving on to better things rather than repeating in cycles—and to the market economy that gave potential inventors the incentive to invent and innovate rather than to focus their energies on competing for slots in the governing bureaucracy.[39] Emphasis on cultural configurations implies that an industrial revolution was inevitable once emerging science combined with a market economy and with the beliefs that nature was there to be mastered; that wealth, comfort, and status could be acquired through mercantile and industrial activity; and that industriousness rather than conspicuous leisure was the virtue most appropriate to the successful.[40]

However, emphasis on cultural configurations as the main source of the industrial revolution has serious problems. Perhaps the most serious is that the German economic sociologist Max Weber—the master of this school—could back at the beginning of the twentieth century dismiss East Asia's prospects for industrialization: its Confucian tradition and value orientation doomed it, in Weber's eyes, to economic stagnation and poverty for as far into the future as he could see.[41]

I tend toward a more "institutional" line of explanation: where there is money to be made and status to be gained, there will emerge personality types to take advantage of the opportunities—and to reassure one another that their success is a mark of their election and favor in this world and (usually) in the next. In all societies different social classes have different modes of understanding, and if the modes of domination and of production are appropriate the mode of understanding conducive to invention, innovation, trade, and manufacture will grow.

After the eighteenth century the flow of inventions became a flood in what was to become the industrial core of today's world economy. Western European governments made it profitable to become inventors by adopting the patent system: the power to devise patent and copyright laws is one of

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[39] David Landes (1998), *The Wealth and Poverty of Nations* (New York: Norton: 0393040178).
[40] The last of these is the famous "Protestant Ethic" of Max Weber. See Max Weber (1904), *The Protestant Ethic and the Spirit of Capitalism* (London: Unwin: 0415084342); and R.H. Tawney (1940), *Religion and the Rise of Capitalism* (London: Peter Smith: 0844614467).
[41] Max Weber (reprint 1979), *Economy and Society* (Berkeley: University of California Press: 0520035003).

the few powers explicitly granted congress by the U.S. constitution. The links between science and industry became close and tight with the invention of electric technologies and with the application of physics to engineering design. Thomas Edison was among the first to assemble a research laboratory: more than fifty mechanics and scientists in a facility in Menlo Park, New Jersey.

[Picture: Edison's laboratory in Menlo Park]

We can very roughly and approximately gauge the increasing technological capability of humanity before the industrial revolution by looking at non-mechanized sources of power. A man works a pump or crank with approximately 1/17 of a horsepower. A man with a horse has roughly half a horsepower at his disposal. That quintessential capital good of the modern Dutch countryside of the seventeenth century—the turret windmill—has perhaps fifteen horsepower. That was the rough limit of pre-industrial—even sophisticated pre-industrial—motive power.

The nineteenth-century industrial revolution moved things a full order of magnitude forward. The energy at the disposal of the average Belgian industrial worker in 1910 was some ten times what his or her own muscles could have provided—half a horsepower per head.[42]

[Picture: Early twentieth century factory]

The first half of the twentieth century saw power at the service of the average manufacturing worker improve roughly fivefold as electricity replaced steam, and as capital accumulation multiplied the number and capability of machines. By 1953 the average American manufacturing worker had roughly three hundred times as much power at his or her disposal as did his or her colonial predecessor of two hundred years before.

Simply counting horsepower understates the change, for the precision with which power and force can be used vastly exceeds what was possible in

[42] Sources of power footnote.

previous centuries as well, and there are many applications where the precise application is more important than the amount of force.[43]

To try to smooth out technological progress into a single, smooth, upward-climbing curve is to do violence to the process. Technology advances in fits and starts, sector by sector. At different times different sectors are "leading" sectors—the prime focuses of technological change, and the places where advances in technology are occurring the most rapidly.

But revolutions in productivity in the economy's shifting set of leading sectors have been ongoing since 1760 or so, the beginning of the industrial revolution. That is why the age starting in 1760 or so is called the age of the industrial revolution. Today microelectronics is one of the leading sectors of technological change: it obeys Moore's law, according to which the number of transistors that can be backed on a chip—and thus the price of a device—halves every eighteen to twenty-four months. Such rapid progress in this particular leading sector, the industry of microelectronics, is new to our generation. But microelectronics is only the latest of a long series of leading sectors.[44]

The economy has cycled through a number of leading sectors over the past two hundred years. First came steam engines to drain coal mines, and then steam engines to power machinery. Then it was the turn of cotton spinning. Then came ironworking. Then came weaving, and railroads. The late nineteenth century saw chemicals, steel-making, railroads again, and electricity as leading sectors of technologial progress. The early twentieth century saw the rise of the internal combustion engine, the automobile, steel-frame construction, and the radio. Textiles, transportation, construction, watches and jewelry, telephones, household utilities, household appliances, broadcasting, textiles again, apparel, air travel, medical care—all have had their turn as leading sectors.

What is going on is not the working-out of the consequences of a single innovation or a single set of technological breakthroughs, but instead a process of continued technological advance that shifts research and development from sector to sector in response to changing potential benefits, research and development costs, and the likely chance of success.

During the "heroic" phase of innovation in any particular industry, the rate of technological progress can be extremely rapid. Consider cars. The

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[43] *From Shafts to Wires.*

[44] Is microelectronics really *just* another leading sector? "New Economy."

average car purchased in 1906 cost $52,640 of 1993-value dollars (after adjusting for inflation; see Raff and Trajtenberg, 1997). By 1910 the average price of a car had dropped to $39,860 of 1993-value dollars—but in 1910 the quality of the average car was 31 percent higher than in 1906: it seemed as if the better something is, the cheaper it will cost. By the time the heroic, entrepreneurial age of the American automobile came to an end in 1918, an average car cost 53 percent less than in 1906 (in inflation-adjusted dollars) and had a quality 105 percent higher.[45]

In all these leading sectors prices fell so much and quality improved so much that any previous century would see the “price” of that sector's output as effectively zero. My wife and I have a small dining room, with a small four-bulb chandelier. But should we go to Monterey for the weekend and leave the dining room light on, by the time we return we will have used as much in the way of artificial illumination as an average pre-1850 American household consumed in a year.

What would have cost them about five percent of their household income in candles, tapers, and matches costs us so little that we cannot see it in our Pacific Gas and Electric bill.

In nearly every sector the bulk of economic value added comes before the heroic period has come to an end. The first railroads connected key points between which lots of bulky, heavy, expensive materials needed to move. The first three TV networks came amazingly close to sating Americans' taste for audiovisual entertainment. The first uses of modern telecommunications and computers—Plain Old Telephone Service, music and news via radio, the first TV networks, Blockbuster Video, scientific and financial calculations, and large database searches—were the highest-value uses.

Later uses are lower-value uses: if they were higher-value uses, they would have been applied to them already. Thus the profits and the excitement die down. Henry Ford perfects the Model T. Cable and Wireless figures out how to properly insulate submarine telegraph cables. The first easy-to-find antibiotics are all classified. And so Moore’s law will someday come to an end. Thereafter microelectronic-based computers and communications will become a much more mature industry—with different focuses for research and development, different types of firms, and different types of competition.

[45] Consequences for society and for styles of life of automobilization and illuminization.

But just because the price of a commodity or service asymptotes at zero during the heroic age of a sector's technological development does not mean that the sector's share of total spending diminishes. Pacific Gas and Electric makes a healthy sum off of my family, even though the candle-makers of 1815 would see it as the next thing to giving away energy for free. But we consume a lot of energy.

After the heroic age, firms make money by giving customers exactly what they want. As long as automobile prices were falling and quality rising rapidly, Henry Ford could do very, very well by riding the leading edge of the technology wave: making a leading-edge car and letting the customer choose the color and the options, as long as the options were zero and the color was black. But after the 1920s Ford got overwhelmed by Alfred P. Sloan's General Motors, which figured out how to retain most of Ford's economies of scale while at the same time proliferating brands, models, styles, and colors to get close to individual consumer demand. Before GM, no one knew what kind of options car buyers really wanted.[46]

[Figure: Comparison of Chevys in 1935 with Model A]

And after the heroic age, some firms inevitably wind up larger than anyone had every imagined possible. Everytime a leading sector goes through a heroic entrepreneurial and technological burst, it changes the opportunities to realize economies of scale. Without the technological innovations of the late nineteenth century, U.S. Steel or Bethlehem Steel would have been impossible—inefficient, and unsustainable. Today we see that the microelectronics revolution is going to leave us with some very large new firms—in all probability in software (write once, run everywhere), in advanced hardware design, and in backbone bandwidth provision.

Each leading sector-based burst of innovation leaves us with previously unimagined capabilities. The railroad gave us the ability to cross the continent in a week rather than in months. Electric power gave us the ability to light our houses. Metallurgy gave us the ability to build some really big buildings and bridges. Microelectronics is giving us the ability to analyze situations based on statistical inference rather than anecdote, and is giving us the opportunity to access any piece of information in a manner of minutes.

[46] General Motors. Danny Quah on the massless economy. Hal Varian and Carl Shapiro.

As our capabilities grow, the salience of our expanded capabilities in the economy—which is, after all, the realm of things that are scarce and thus have market value: air has never been part of the economy—does not. Thus, as William Baumol noted, a larger share of the labor force finds itself employed in precisely those sectors that have not been transformed recently by new technologies.[47]

The forward advance of technology has not just direct but indirect effects on productivity and living standards. Because of the demographic transition, a richer economy is an economy with lower population growth. Less of national savings and investment needs to be devoted to simply equipping an expending labor force with the tools they need to become effective producers. More of national savings and investment can be devoted to "capital deepening"—to increasing the stock of machinery, equipment, and other capital goods available to multiply individual productivity.[48]

Moreover, a richer economy is one that is disproportionately more efficient at making the industrial goods—especially the industrial capital goods—that are at the heart of the process of industrialization and development. A lower relative price of capital goods in a high-productivity industrial economy means that the same share of nominal national product saved translates into a larger addition to the economy's capital stock.

Thus a one percent improvement in technology broadly construed—in the economy's total factor productivity—has the potential to call forth not a one but at least a four and possibly a ten percent boost to the level of output per worker along the economy's long-run steady-state growth path.

How long will the leap forward of technology based on science and technology continue?

There might have been a time when people might have thought that the industrial revolution would run its course: the industrial revolution of the eighteenth and nineteenth centuries was based on power (first steam, then electricity and gasoline), simple automation using power (looms and spinning machines), and metalworking. Perhaps at some point the pace of productivity improvement in these technologies would begin to slow. But power, simple automation, and metalworking were followed by industrial revolutions in chemicals and in artificial materials; in transportation; in

[47] Cite to Baumol and "cost disease." Does it mean the eventual end of economic growth? Probably not, or at lest not obviously…

[48] These arguments are developed at greater length in chapter 7.

communications; and then in microelectronics and information processing—not to mention the atomic bomb.[49]

So far there are no signs that invention and innovation have begun to run into increasing returns. The technological density of the world continues to grow. If limits are approaching, they are not visible yet.[50]

[49] Footnote to Herman Kahn. Not all technology is obviously a good thing.
[50] Logistic curves vs. singularities. Von Neumann machines. Doomsday models.