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Modern Economic Growth in the Long 20th Century, 1870-2016

J. Bradford DeLong
U.C. Berkeley & WCEG

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A Grand Narrative

History is never one story. And history's stories do not have one single thread. You might point out that there have been too many Grand Narratives over the past four centuries. They all heavily, heavily imply that one big thing happened, that it is over (or about to be over), that everything else revolves around that one big thing, and that we clearly know what the one big thing means.

But go down the road fifty, a hundred, whatever years after anyone has written a Big History with a Grand Narrative. You find that, no, they did not know what it meant. That always happens. We find that it was not the end but only the middle of the story. Or we find that there were other, more important stories, burbling along that we should have paid more attention to—and that we would have paid more attention to, had we not been busy cramming everything and everyone into the Procrustean Grand Narrative.

Pounding history into a Procrustean Bed of a narrative, you declare, is fuzzy thought. It leads to bad judgments.

But we have to tell Grand Narratives if we are to think at all.

We have to think in narratives. Our intelligence is not that well developed. We are bears of very little brain. And stories are how we make sense of things, and how we remember.

Grand Narratives are, in the words of that bellwether 20th century philosopher Ludwig Wittgenstein, "nonsense". But so is all human thought. But our fuzzy thoughts are the only ways we can think—the only ways we have to climb up. Then, as Wittgenstein says, if we are lucky one can, "recognize… them as nonsensical. After we have "used them—as steps—to climb beyond them… [and then] throw[n] away the ladder," for, perhaps, we will have learned to transcend "these propositions, and then… see the world aright".

And because we crave stories that make sense to us, we choose the central themes that we do because they are of interest, and sometimes of importance, to us.

I maintain that I have chosen this Grand Narrative as the best and most important one to tell about the world of our parents, grandparents, great-grandparents, and great-great-grand parents. I also think it holds out the promise of improving the lives of subsequent generations.

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This is my Grand Narrative:

The Long 20th Century of Modern Economic Growth began around 1870, when the triple emergence of globalization, the industrial research lab, and the modern corporation in the context of the market economy set the world on the path that pulled it out of the dire poverty that was humanity's lot in all centuries before; and when America took the steps that made it the place where much of the action was —"the furnace where the future is forged," to quote Russian Revolutionary Leon Trotsky.

The Long Twentieth Century ended in 2016, with the sharp shock of the near-return of Great Depression-era macroeconomic conditions; with the failure of the anemic economic recovery from the Great Recession that started in 2008 to bring a restoration of the post-1870 pace of productivity growth; and with the election of Donald Trump, an American president hostile to global leadership, to global cooperation, and to the very ideas that America was open to immigrants.

It was, I think, the most consequential single century humanity has had and, hopefully, will have. And it was the first century in which the most consequent historical thread was what I would call *economic*.

That is a claim worth pausing over. These are decades that witnessed, among much else, two world wars, the Holocaust, the rise and fall of the Soviet Union, the zenith of American influence, the rise and ascension of Communist China, and more. Vast political, cultural, and social forces were at work alongside and sometimes due to the decisions, celebrated and damned, of numerous individuals, celebrated and damned, of unique influence. Yet I still unhesitatingly declare the most consequent thread through all this history was economic.

Before 1870, over and over again technology lost its race with humanity's high fertility. Greater numbers coupled with resource scarcity and a slow pace of technological innovation produced a humanity where most people most of the time could not be confident that in a year they and their families would have their 2000 calories, plus essential nutrients, plus a roof over their heads. Before 1870 those successfully on the make had to do so overwhelmingly focusing on how to take from others and then keep what they had while maintaining order, rather on how to make more for everyone.

The ice was breaking before 1870. Between 1770 and 1870 technology and organization gained a step or two or three on high fertility. But only a step or two or three. Any post-1870 slackening of the pace of technological or organizational progress, or any major redivision of society's dividends devoting less to the sinews or peace and more to the sinews of war, and the "nasty, brutish, and short" of previous ages would have reasserted itself. In the early 1870s that British establishment economist, moral philosopher, and bureaucrat John Stuart Mill continued to claim that "it is questionable if all the mechanical inventions yet made have lightened the day's toil of any human being…"

The consequences of the 20th century have been enormous: Today less than 9% of humanity lives at or below the roughly $2-a-day living standard we think of as "extreme poverty", down from 70% or so 1870. And even those 9% have access to public-health and mobile phone-communications technologies of vast worth and power. Today the economies of the world lucky enough to be rich stand at levels of per-capita prosperity at least twenty (and possibly much more) times those of 1870 and at least twenty-five (and possibly much more) times those of 1770, with every expectation of further doublings in the centuries to come. Today the typical citizens of those economies can wield powers—of mobility, of communication, of creation, and of destruction—that approach if they do not surpass those attributed to sorcerers and gods in ages past. Even the majority living in economies unlucky and in the "Global South" confront not the $2-3 a day living standard of those economies in 1800 or 1870, but $15 a day (and more).

Tell any of those in previous centuries about the wealth, productivity, technology level, and sophisticated productive organizations of the world today, and they would say that with such power and wealth in our collective hands we must have built a utopia.

Perhaps the third best-selling novel in the United States in the 19th Century was *Looking Backward, 2000-1887*, by Edward Bellamy. Bellamy was a populist and—although he rejected the name—a socialist: he dreamed of a utopia created by government ownership of industry, the elimination of destructive competition, and the altruistic mobilization of human energies in a way analogous to his vision of the North's collective effort to end slavery in the Civil War. Technological and organizational abundance would then generate a society of abundance. He therefore wrote a "literary fantasy, a fairy tale of social felicity" as a "hanging in mid-air, far out of reach of the sordid and material world of the present… cloud-palace for an ideal humanity".

He throws his narrator-protagonist forward in time from 1887 to 2000 to marvel at a well-working rich society. At one point the narrator-protagonist is asked, "Would you like to hear some music?" He expects his hostess to play the piano. This alone would be testament to a vast leap forward. To listen to music on demand around 1900 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. Then there would be the expense and the time committed to piano lessons.

But Bellamy's narrator-protagonist is awed when his hostess does not sit down at the pianoforte to amuse him and exhibit her ladylike domestic accomplishments. Instead, she "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?'"

He learns that his host has dialed up, on her telephone landline, a live local orchestra playing in the city, and she has put it on the speakerphone. In Bellamy's utopia, you see, you can dial up a local orchestra and listen to it play live. But, wait. It gets more impressive. He further learns he has a choice. His hostess could dial up one of four orchestras currently playing.

Bellamy's narrator's reaction?

> 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...

Think of that: *the limit of human felicity.*

Utopias are, by definition, the end-all be-all. "An imaginary or hypothetical place or state of things considered to be perfect; a condition of ideal perfection," so says the Oxford English Dictionary. Much of human history has been spent in disastrous flirtations with ideals of perfection of many varieties. Utopian imaginings during the long twentieth-century were responsible for its most shocking grotesqueries. It was also the century during which humanity's willingness to lose itself to such imaginings declined. Another bell-weather 20th century philosopher, Immanuel Kant, wrote, "Out of the crooked timber of humanity no straight thing was ever made," inspiring philosopher-historian Isiah Berlin to note, "And for that reason no perfect solution is, not mere in practice, but in principle possible in human affairs."

Berlin goes on to write, "and any determined attempt to produce it is likely to lead to suffering, disillusionment, and failure." This also points to why I see the long 20th century as most fundamentally economic. For all its uneven benefits, for all its expanding human felicity without ever reaching its limit, for all its manifest imperfections, economics during the 20th century has worked just shy of miracles.

Many technological inventions of the past century have transformed experiences that were rare and valued luxuries—available only to a rich few at great expense at relatively rare performances of the symphony or the opera—into features of modern life that we take so much for granted that they would not make the top twenty or even the top 100 in an ordered list of what we think our wealth consists of us. If you asked Edward Bellamy—or any other nineteenth-century or earlier sketcher of utopias—whether we here today have the knowledge of technology and of productive organization needed to provide at least the material abundance needed to build a utopia, they would all say "of course." Indeed, Bellamy, on confronting a Pandora playlist, would have to admit that we have *exceeded* the limit of human felicity.

And yet. We today—even the richest of us—rarely see ourselves as so extraordinarily lucky and fortunate and happy even though *for the first time in human history there is more than enough*.

There are more than enough calories produced in the world that it is not necessary that anybody need be hungry.

There is more than enough shelter on the globe that it is not necessary that anybody need be wet.

There is more than enough clothing in our wearhouses that it is not necessary that anybody need be cold.

And there is more than enough stuff lying around and daily being produced to aid daily life that nobody need feel under the pressure of lack of something necessary.

We are no longer in anything that we could call "the realm of necessity." So, one would think we humans ought to be in something recognizably utopian.

That we cannot is another consequence of living lives fully in the stream of economic history. While history fueled by utopian aspirations is an all or nothing proposition, economic history's successes and failures are most often experienced in the margins.

Which is partially why no full-throated triumphalism over the long twentieth century can survive even a brief look at the political economy of the 2010s: the stepping-back of the United States from its role of good-guy world leader and of Britain from its role as a key piece of Europe; the rise in politics in North America and Europe of movements that reject democratic representative consensus politics in favor of allegiance to not so much a new growth as a revival of an old crop of leaders. Leaders whose principal qualifications are their desires to strike at external foes and at internal fifth columns. Leaders of movements Madeleine Albright calls "fascist" (and who am I to tell her she is wrong?). Indeed, the opposite of triumphal is the conspicuous failure over the previous decade by the stewards of the global economy to either maintain or to rapidly return to full employment, and to nurture equitable growth rather than rising plutocracy.

Yes, over 1870-2016, technology and organization repeatedly lapped fertility. Yes, then the psychology of a newly richer humanity in which girls learned to read and acquired social power permanently scotched Malthusian forces from their role as the fetters of humanity. But material prosperity is grossly, criminally unevenly distributed around the globe. And material wealth does not make people happy in a world where politicians and others prosper mightily from finding new ways to

make and keep people unhappy. The history of the Long 20th Century cannot be told as a gallop, run, a march, or even a walk of progress along the road that brings us closer to Utopia. It is, rather, a slouch. At best.

Having *more than enough is*, somehow, not enough.

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Slouching, however, is better than standing still, let alone going backwards. That no generation of humanity has ever disputed. Humans have always been inventive. Technological advance has rarely stopped. The windmills, dikes, fields, crops, and animals of Holland in 1700 made the economy of its countryside very different indeed from the thinly-farmed marshes of 700. The ships that docked at the Chinese port of Canton had much greater range and the commodities loaded on and off them had much greater value in 1700 than in 800. And both commerce and agriculture in 800 were far more technological advanced than that the first literate civilizations of -3000 or so.

But before our age, back in the pre-industrial Agrarian-Age, technological progress led to little visible change over one or even several lifetimes; and little growth in typical living standards even over centuries or millennia.

I can and do—heroically—construct an index of the value of the stock of useful human ideas about manipulating nature and organizing human effort—an index of our "technology", as economists call it. I assume that each 1% increase in typical human standards of living worldwide tells us that the value of the stock of useful ideas has risen by 1%. I assume that each 1% increase in the human population at a constant typical living standard tells us that the value of useful ideas has risen by 0.5%—for such an increase is necessary to hold living standards constant in the face of the smaller average farm sizes and other Malthusian *per capita* resource scarcities that emerge from a higher population. (Where does the ⅓ come from? It is a heroic guess: a judgment that natural resources are, in the average and over time, roughly half as important as human brains, eyes, hands, and muscles in boosting production.) This is simply a way of taking account of the fact that, since our natural resources are not unlimited, human ingenuity is as required to support a larger population at the same standard of living as to support the same population at a higher standard of living.

Set this quantitative index of the global value of useful human knowledge equal to a value of 1 at the beginning of the Agrarian Age, at the discovery of farming about

8,000 years ago. In year 1 this-of-the-stock-of-ideas index stood at 3.5: with the same resources at their disposal, better "technologies" meant that the typical worker in year 1 was 3.5 times as productive as in the year -6000. By the year 1500 the stood at 4.7.

These are impressive changes. And, indeed, from the standpoint of -6000 the technologies of the year 1500, the Ming pottery or the Portuguese caravel or the wet-cultivation of rice seedlings, are very impressive. But this growth, and the pace of invention, took enormous spans of time: 0.02% per year for the entire span years from 1 to 1500—that is only 0.5% over an average 25-year lifetime of that age.

And did greater knowledge about technology and human organization cause life in 1500 to be much sweeter than it had been in 8000 BC? It turns out not. The human population grew at an average rate of 0.06% per year from year 1 to 1500. While the elite lived far better in 1500, typical human peasants and craftsmen lived little or no better than their predecessors.

Agrarian Age humans were desperately poor: a subsistence-level society. On average 2.03 children per mother survived to reproduce. A typical woman (who was not among the one in seven who died in childbirth or the additional one in five who died before her children were grown) spent perhaps 20 years eating for two: nine pregnancies, six live births, three children surviving to age five, and the life expectancy at birth of her children under and perhaps well under 30.

Keeping your children from dying is the first and highest goal of every parent. Humanity in the Agrarian Age could not do so. That is an index of how much pressure from material want humanity found itself under.

Over the millennia, 1.5% average population growth per generation added up. In 1500 there were about three times as many people as had lived in year 1. Five hundred million rather than 170 million. Additional humans did not translate to less individual material want. As of 1500 advances in technological and organizational knowledge went to compensate for fewer natural resources *per capita*. Thus economic history remained a slowly-changing background in front of which cultural, political, and social history took place.

The ice started to break after 1500. Or perhaps a better metaphor is crossing a divide and entering a new watershed— you are now going downhill, and things are flowing in a different direction. That happened after 1500, and we call it the "Commercial Revolution". The pace of inventions and innovation sped up. And

then a second watershed was crossed around 1870: we call the century before 1870 the "Industrial Revolution" for a reason. By 1870 the heroic-assumptions index of the value of knowledge stood at 16: more than three times its value of 1500. It had taken 7500 years to nearly quintupled from 1 to 4.7. Then in 370 years it more than tripled to 15.

But there were then 1.3 billion people alive, and so farm sizes were only two-fifths as large as they had been in 1500. The bulk of human population was still in or on the edge of the extreme poverty.

And then around 1870 we crossed over into a third new watershed. So it was during the Long 20th Century that there came explosion.

Our 7.8 billion people today have a global value of knowledge index of 420. Pause to marvel. The value of knowledge about technology and organization grew at an average rate of 2.3% per year. Since 1870, the technological capability and material wealth of humankind has exploded beyond previous imagining. Today the typical human family no longer faces as its most urgent and important problem how to acquire for the next year—or the next week—enough food to avoid being desperately hungry, enough shelter to avoid the elements, and enough clothing.

From the techno-economic point of view, 1870-2016 was the age of the industrial research lab and the bureaucratic corporations. One gathered communities of engineering practice that supercharged economic growth, the other communities of competence that deployed the fruits of invention. It was only slightly less the age of globalization: cheap ocean and rail transport that destroyed distance as a cost factor and allowed humans in enormous numbers to seek better lives, and communications links that allowed us to talk across the world in real time.

The research laboratory, the corporation, and globalization powered the wave of discovery, invention, innovation, deployment, and then global economic integration that have so boosted our global useful-economic-knowledge index. Marvel still. In 1870 the daily wages of an unskilled male worker in London, the city then at the forefront of world economic growth and development, would buy him and his family about 5,000 calories worth of wheat-made bread each. That was progress: in 1800 the daily wages would have bought him and his family perhaps 4000 coarser-bread calories, and in 1600 some 3000 calories, coarser still. (But isn't coarser, more fiber-heavy bread better for you? Yes—if you are getting enough calories. In the old days you were desperate to absorb as many calories as possible, and for that whiter and finer bread is better.) Today the daily wages of an

unskilled male worker in London would buy him 2,400,000 wheat calories: nearly 500 times as much.

From the bio-sociological point of view, the wealth creation process of 1870-2016 drove it to be *the* century in which it ceased to be the case that the typical woman spent twenty years eating for two—pregnant or breastfeeding. Today, it is more like four years. And it was the century in which we stopped watching more than half our babies die in miscarriages, stillbirths, and infant mortality—and stopped watching more than a tenth of mothers die in childbed.

From the nation-and-political point of view, that wealth creation and distribution process drove four things, of which the first was by far most important: It made 1870-2016 the century in which the United States of America was a superpower, a *hyperpower*, a *hegemon*. Second, it made a world primarily of nations rather than of empires. Third, it made an economy with a center of gravity consisting of large oligopolistic firms ring-mastering value chains. Finally, it made a world in which political orders would be primarily legitimated, at least notionally, by elections with universal suffrage—rather than the claims of plutocracy, tradition, "fitness," leadership charisma (usually in the service of the exaltation of a particular largely-fictitious *ethnos*), or knowledge of a secret key to historical destiny.

Much that our predecessors would have called "utopian" has been attained step by step, via economic improvements year by year, each of which is marginal, but which compound.

Yet as of 1870 such an explosion was not foreseen, or not foreseen by many. Yes, 1770-1870 did see, for the first time, productive capability begin to outrun population growth and natural resource scarcity. By the last quarter of the nineteenth century, the average inhabitant of a leading economies—a Briton, a Belgian, a Dutchman, an American, a Canadian, or an Australian—had perhaps twice the material wealth and standard of living of the typical inhabitant of a pre-industrial economy.

Yet was that enough to be a true watershed?

Back in the early 1870s John Stuart Mill, Britain's leading economist, moral philosopher, public intellectual, and feminist activist (arrested for distributing birth control leaflets in the streets of London), put the finishing touches on the final edition of *the* book that people seeking to understand economics then looked to: *Principles of Political Economy, with Some of Their Applications to Social*

Philosophy. His book gave due attention and place to the 1730-1870 era of the British Industrial Revolution. But he looked out on what he saw around him, and saw the world still poor and miserable. "Hitherto", he wrote, looking at the world and at the Great Britain and Ireland of his day:

> it is questionable if all the mechanical inventions yet made have lightened the day's toil of any human being. They have enabled a greater population to live the same life of drudgery and imprisonment, and an increased number of manufacturers and others to make fortunes. They have increased the comforts of the middle classes...

One word in Mill's paragraph stands out to me: *imprisonment.*

With more and richer plutocrats, a larger middle class, but the world Mill saw as of 1871 was not just a world of drudgery—a world in which humans had to work long and tiring hours at tasks that came nowhere near to being sufficiently interesting to engage the full brainpower of an East African Plains Ape. The world Mill saw was not just a world in which most people were close to the edge of being desperately hungry. The world Mill saw was not just a world of low literacy—where most could only access the collective human store of knowledge, ideas, and entertainments partially and slowly. The world Mill saw was a world in which humanity was *imprisoned:* not free, in a dungeon, chained and fettered. And Mill saw only one way out: if the government were to take control of human fertility and require child licenses, prohibiting those who could not properly support and educate their children from reproducing, only then—or was he thinking "if"?—would mechanical inventions wreak the "great changes in human destiny, which it is in their nature and in their futurity to accomplish."

And there were others who were much more pessimistic than even Mill. In 1865 then 30-year old British economist William Stanley Jevons made his reputation by prophesying doom for the British economy: it needed to start, immediately, cutting back on industrial production in order to economize on scarce and increasingly valuable coal.

Not only was it not foreseen, not only was the explosion in economic growth not foreordained, it was dangerously misconstrued by some.

Karl Marx and Friedrich Engels had in 1848 already seen science and technology as Promethean forces that would allow humanity to overthrow its (mythical) old gods and give humanity itself the power of a god. Science, technology, and the

profit-seeking entrepreneurial business class that deployed it had:

> during its rule of scarce one hundred years,…created more massive and more colossal productive forces than have all preceding generations together. Subjection of Nature's forces to man, machinery, application of chemistry to industry and agriculture, steam-navigation, railways, electric telegraphs, clearing of whole continents for cultivation, canalisation of rivers, whole populations conjured out of the ground—what earlier century had even a presentiment that such productive forces slumbered in the lap of social labour?…

Engels snarked that in their overlooking of the power of science, technology, and engineering mere economists (like Mill) had demonstrated that they were simply the paid hacks of the rich.

But Marx and Engels's promise was not that there would someday be enough to eat, shelter, clothing, let alone the exponential increase in the value of global knowledge, or even a nearly unlimited choice of music to listen to. Slouching, galloping economic growth was but a necessary paroxysm on the way to utopia. Marx's few and thin descriptions in works like his *Critique of the Gotha Program* of life after the socialist revolution he foresaw as inevitable echo—deliberately, but with what authorial intent?—the descriptions of how people who have attained the Kingdom of Heaven behave: each will contribute "according to his ability" (*Acts of the Apostles*: 11:29) and each will draw on the common, abundant store "according to his needs" (*Acts of the Apostles* 4:35). And Mill hoped for his version of the same thing: an end to the imprisonment and drudgery of poverty, and then in a society rightly ordered by the principles of his libertarianism, all people could be truly free.

But economic improvement, attained by slouch or gallop, matters.

How many of us today could usefully find our way around a kitchen of a century ago? Before the coming of the electric current and the automatic washing machine, doing the laundry was not an annoying but minor chore but was instead a major part of the household's—or rather the household's women's—week. Today few among us are gatherers, or hunters, or farmers. Hunting, gathering, farming, herding, spinning and weaving, cleaning, digging, smelting metal and shaping wood, assembling structures by hand—those are now the occupations of a small and dwindling proportion of humans. And where we do have farmers, herdsmen, manufacturing workers, construction workers, and miners, they are overwhelmingly controllers of machines and increasingly programmers of robots.

They are no longer people who make or shape things—*facture*—with their hands—*manu*.

What do modern people do instead? Increasingly, we push forward the body of technological and scientific knowledge. We educate each other. We doctor and nurse each other. We care for our young and the old. We entertain each other. We provide other services for each other to take advantage of the benefits of specialization. And we engage in complicated symbolic interactions that have the emergent effect of distributing status and power and coordinating the 7.4-billion person division of labor of today's economy.

We have crossed a great divide between what we used to do in all previous human history, and what we do now. Utopia, it is true, it is not.

USC economic historian Richard Easterlin noted the assumption from psychologist Abraham Maslow's hierarchy of wants that "the satisfaction of material wants is but one, lower, stage in human evolution and that economic growth brings with it a movement toward higher nonmaterialistic ends"—ends fitting for humans in Utopia, or at least pursuing Aristotle's eudaemonia. He noted that historical experience told us that was not so.

With increasing wealth, what were necessities cease to be of concern or even notice in our minds. But conveniences turn into necessities. Luxuries turn into conveniences. And we envision and then create new luxuries.

Easterlin, bemused, puzzled over how "material concerns in the wealthiest nations today are as pressing as ever, and the pursuit of material needs as intense." He saw humanity on a hedonic treadmill, with "generation after generation think[ing] it need[ed] only another ten or twenty percent more income to be perfectly happy…. In the end, the triumph of economic growth is not a triumph of humanity over material wants; rather, it is the triumph of material wants over humanity." We do not use our wealth to overmaster our wants. Rather, our wants use our wealth to continue to overmaster us.

But only a fool would wittingly or ignorantly slouch or gallop backwards to near-universal dire global poverty.

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The consequences of the changes that made the Long 20th Century what it was—

the industrial research lab and the associated communities of engineering practice, by the modern corporation and its powers to bureaucratically distribute and diffuse knowledge into production worldwide, and by globalization that moved hundreds of millions of people from continent to continent and brought all places cheek-by-jowl, as far as shipment of non-fragile staples was concerned—ramified far. I count ten ramifications, which are themselves themes of the many substories I tell:

The source of all, from which all else flows, was the without-any-precedent **explosion of material wealth:** that the Long 20th Century saw the material wealth of humankind explode beyond all previous imagining so that we—at least those of us who belong to the upper middle class and live in the industrial core of the world economy—are now far richer than the writers of even previous centuries' utopias could imagine.

1. **History was economic**: As a result of the economic changes that were the explosion of wealth, the Long 20th Century was the first century ever in which its history was predominantly economic. The economy was the dominant arena of events and change, and economic changes were the driving force behind other changes, in a way never seen before in any single century.

2. The **expanding cornucopia of technological knowledge:** Enabling the enormous increase in material wealth—its essential prerequisite, in fact—was the explosion in human technological knowledge. This required not just a culture and educational system that created large numbers of scientists and engineers, and means of communication and memory so that they could stand on each others' shoulders as well as those of earlier giants, but also that the market economy be structured in a way that made it worth people's while to funnel resources to scientists and engineers so that they could do their jobs.

3. The **victory of public health**: Typical human lifespans went from 25 to 70 or more years. They did this despite how globalization brought new plagues and types of plagues—the 1918-1919 influenza epidemic and, just beyond our end point, the 2020 coronavirus epidemic. Enough said: that increase in life expectancy by itself meant that humanity at the end of the Long 20th Century was living in what all previous eras would have regarded as a fabulous utopia.

4. The **demographic transition:** The Long 20th Century saw, we think, the approaching end of the era in which technology and biology increased human numbers: it looks like the world is headed for zero population growth at a population of roughly 10 billion in 2050. And during the Long 20th Century the

population explosion that carried the earth from 1 to 7.5 billion people placed huge demographic burdens on poor countries—burdens now ebbing as the demographic transition to low fertility and extended lifespan finish their spread across the globe.

5. **Feminism:** The Long 20th Century saw the substantial liberation of women from the role imposed by patriarchy and Malthusian pressures. At the start of the Long 20th Century the typical woman spent about 20 years eating for two: pregnant or breastfeeding. At the end of the Long 20th Century the typical woman spent about 4 years. Should this be theme number one? Perhaps.

6. **American exceptionalism:** Resources—derived by conquest—and ingenuity produced wealth and prosperity in the United States beyond the measure of that attained in any other portion of the globe. That prosperity fueled the ascent—economic, military, cultural, and political—of an America committed extremely imperfectly to broad principles of democracy, rule of law, and human rights. All of these proved supportive in varying measure to economic growth and the prospering of human potential. Even those philosophically or practically opposed to freedom of speech, religion, occupation, and thought and fearful of democracy had to reckon with their immense attractiveness to many in their own land, and to the observed correlation between American aspirations, American institutions, and American prosperity and power.

7. **Progress toward inclusion and hierarchy attenuation:** To an extent that earlier human observers would have found hard to credit, human societies became, to a remarkable degree, much less instrumentalities for advancing the interests and comforts of men of the right background—and global society became, to a degree that would have seemed even more remarkable to human observers as of 1870, much less instrumentalist for advancing the interests and comforts of men of a white northwest-European background. Even if it is still the case that "white males play the videogame that is society on the 'easy' setting," others began to count.

8. **Tyranny multipliers:** The Long 20th Century's tyrannies were more brutal and more barbaric than those of any previous century—and these tyrannies were in strange, complicated, and confused ways closely related to the forces that made the explosion of wealth so great.

9. **Wealth gulfs:** The Long 20th Century saw the relative economic gulf between different economies grow at an astonishingly rapid pace as the world became,

relatively, a more unequal place than ever before—save possibly for the days when some East African Plains Apes knew how to make fire and others did not. It is a scandal and a disgrace that today one-quarter of the human race have lives that—save for public health—are not that distinguishable from the lives of our Agrarian Age predecessors.

10. Finally, **Disorganization, mismanagement, insecurity, and dissatisfaction:** The governments of the Long 20th Century had little clue as to how to regulate the un-self-regulating market to maintain prosperity, or ensure opportunity, or produce substantial equality.

Engrave these themes on your brains. The only way I know for me to do that is to tell you the story, and the substories. The place to start is in the year 1870, with humanity still in the clutches of the Devil of Malthus:

Globalizing the World, 1870-1914

In 1870 most of humanity was still, as it had long been, firmly trapped in the clutches of the Devil of Malthus.

Just before 1800 English scholar and cleric Thomas Robert Malthus's *Essay on the Principle of Population* set out what he saw as the menace to human prosperity: Improve productivity to increase the food supply? Population will increase as well, and push nutrition standards back down. A grim standard of living with just enough for population to grow on average as fast as improving technology allows, but not much more, was the lot of the vast majority. Even as the end of the 1800s came into view, at least some smart money—remember John Stuart Mill—still bet that there had not yet been any decisive watershed in human destiny.

Had the Industrial Revolution of 1770-1870 lightened the toil of the overwhelming majority of humanity—even in Britain, the country at the leading edge? Doubtful. Had it materially raised the living standards of the overwhelming majority—even in Britain? By a little. Worldwide, compared to everything before, it had been a big deal: steam power and iron-making and power looms and telegraph wires had provided comforts for many and fortunes for a few. But how humans lived had not been transformed. And there were legitimate fears. It was as late as 1919 British economist John Maynard Keynes had written that while "Malthus['s]… Devil… [had been] chained up and out of sight", in the catastrophe of World War I "perhaps we have loosed him again…"

A fixation on food makes compelling sense to the hungry. From the year -1000 to 1500 human populations, checked by available calories, had grown at an average annual snail's pace growth rate of 0.09% per year: from perhaps 50 million to perhaps 500 million. Lots of children, but too malnourished for enough of them to thrive and survive to boost population rapidly. Over these millennia typical standards of living of peasants and craftworkers changed little: they spent half or more of their available energy and cash securing bare-essential calories and nutrients.

It could hardly have been otherwise. Malthus's Devil made that certain. Population growth largely ate the benefits of invention and innovation in technology and organization, leaving only the exploitative upper class noticeably better off. And

the average pace of invention and innovation in technology and organization was anemic: perhaps 0.04% per year, compared to the early 21st century's 2.1% per year.

In 1500 came a watershed: the Commercial Revolution. The rate of growth of humanity's technological and organizational capabilities took a fourfold upward leap: from 0.035% per year to 0.2% per year. The ocean-going caravels, printing presses, canals, and clocks that had emerged by 1700 were visible technological marvels. But this growth was not fast enough to break Malthus's trap of near-universal poverty.

Globally the rich began to live better. But the typical person saw little benefit—or perhaps a substantial loss. Better technology and organization brought increases in production, but of all types. This included the production of more powerful and more organized brutality delivering killing, conquest, and slavery.

In 1770 came another post-1500 watershed: the British Industrial Revolution. The rate of growth of humanity's technological and organizational capabilities took another upward leap, roughly threefold from 0.15% per year to around 0.45%. From 1770 to 1870 more technological marvels became commonplace in the North Atlantic at this more rapid pace, and visible throughout much of the world. Global population growth accelerated to about 0.5% per year, and for the first time global production may have exceeded what we would see as 3 dollars a day per head.

0.04% - 2.1% - 0.035% - 0.2% - 0.15% - 0.45% - 0.5%- $3.00. The numbers are important—indeed, they are key. As economic historian Robert Fogel said to me once—echoing my great-great uncle economic historian Abbott Payson Usher—The secret weapon of the economist is the ability to count. Remember: we humans are narrative-loving animals. Stories with an exciting plot and an appropriate end of comeuppances and rewards fascinate us. They are how we think. They are how we remember. But individual stories are only important if they are of individuals at the crossroads whose actions actually decide on humanity's path, or of individuals who are representative of the now-billions of stories in the naked world. And only by counting can we tell which stories are at all representative, and which differences in path truly matter.

The causes of the Industrial Revolution were not foreordained. It was not inevitable. For me to survey the debate over its causes and its near- or lack of necessity is outside the scope of the book. There are likely other worlds out there like ours in their history up to 1500, worlds sharing our space and time, but worlds

that we cannot hear or see or touch just as a radio does not hear all of the other electromagnetic waves of all the stations but only the one to which it is tuned. In the bulk of those worlds, I think, there was no British Industrial Revolution. Commercial Revolution-era growth of 0.15%/year or a reversion to mediæval growth of 0.035%/year is what they see: a world of, semi-permanently, Gunpowder Empires and sail-driven global commerce.

But I do not think that the Commercial and the British Industrial Revolutions were decisive.

Consider that the 0.45% per year rate of growth of human technological and organizational capabilities typical of the Industrial Revolution era would have been eaten up by global population growth of 0.9% per year. A population living at 4 dollars a day could and would sustain that population growth rate. And in the late nineteenth century artificial means of birth control were not widespread. There was, instead, high infant mortality in tension with a near-universal desire for parents to have enough children to make sure some survived to take care of them as they aged, should one be lucky enough to have an old age. And in the late nineteenth century population growth was accelerating.

0.45% rate of growth in the useful-ideas stock was not enough to keep the Malthusian Devil firmly confined in its containing pentagram.

Without a further acceleration—a bigger than Industrial Revolution acceleration—of the underlying drivers of economic growth, today's world might indeed be Permanent Steampunk World. It might have a global population of our current 7.5 billion, but the vast majority living at little more than the 1800 global standard of living. With global technology and organization today at about the level of 1910, with the æroplane an infant technological novelty, and with the disposal of horse manure a principal urban transportation-management problem. We might have not 9% but rather more like 50% of the world living on 2 dollars per day, and 90% living below $5. Average farm sizes would be one-sixth of what they had been in 1800, and only the uppermost of the upper classes would have what we today regard as a Global-North middle-class standard of living.

Permanent Steampunk World, of course, is not what happened. What did was post-1870 innovation growth acceleration: a third watershed.

Around 1870 the proportional rate of growth of humanity's technological and organizational capabilities took a further fourfold upward leap, from perhaps

0.45% per year to our current 2.1% per year or so. Thereafter technology far outran population growth. And thereafter population growth in the richest economies began to decline: humans became rich enough and long-lived enough that limiting fertility became a desirable option. Each year from 1870 to 1914 John Stuart Mill's belief that the progress of science and technology, of industry and enterprise had not lightened the day's toil of any human being or effected great changes in human destiny became less and less true. By 1914 it had become more-or-less completely false.

1870-1914 was, in the perspective of all previous eras, "economic El Dorado… economic Utopia…" The words are Keynes's, looking back from 1919.

The resulting world of 1914 was an odd mix of modernity and antiquity. Britain burned 194 million tons of coal in 1914. The total coal-equivalent energy consumption of Britain today is only 2.5 times that. Yet 1870 still saw close to half of Americans working outside in agriculture. And all European countries with the exception of Belgium and Britain, were behind America in their distribution of the labor force between town and country, and among farming, manufacturing, and other sectors. U.S. railroads carried passengers some 350 miles per citizen in 1913. Today U.S. airlines carry passengers 3000 miles per citizen. Yet all of Europe save France still saw the powerful political and social dominance of agrarian landlords, who still mostly saw themselves as descendants of knights who had fought for their kings with their swords.

Yet it was, compared to the past, near-utopia. Globally, real wages of unskilled workers in 1914 were half again above their levels of 1870. Such a standard of living had never been attained before since we moved to the farm.

Why does each year since 1870 see as much technological and organizational progress as was realized ever four years from 1770 to 1870? Or, as was realized every twelve from 1500 to 1770? Or, as was realized every sixty years before 1500? And how did what was originally a geographically-concentrated surge in and around parts of Europe become a global phenomenon, albeit unevenly global?

I think the keys were the coming of the industrial research laboratory and the large modern corporation. Inventors like Thomas Edison and Nikola Tesla could then be inventors. They did not have to fulfill the ten other roles that their predecessors had had to fill, from impresario to HR manager. This made a huge difference. Technologies could then be rationally, routinely, and professionally developed; and then they could be rationally, routine, and professionally deployed.

Was their development around 1870 necessary and inevitable? We can see how many thing in history are neither inevitable nor necessary—how counterfactuals, might-have-beens, might easily, well, have been. Lillian Cross does not hi assassin Giuseppe Zangara with her purse on February 15, 1933, and so his bullet finds the brain of President-Elect Franklin Delano Roosevelt rather than the lung of Chicago Mayor Anton Čermák; Roosevelt dies and Čermák lives; and America's history in the Great Depression years of the 1930s is very different. But the creation of the industrial research lab was not the action of one, or of only a few, humans. It took many working together and at cross-purposes taking years.

We feel that that process could have worked out differently. But we have no good way to conceptualize how, or what the plausible range of drift to different outcomes was. We are right to feel that it could have worked out differently. As Anton Howes points out, nearly any weaver for 5000 years before 1773 could have made their life much easier by inventing the flying shuttle. None did until John Kay, who had no deep knowledge and used no advanced materials, just "two wooden boxes on either side to catch the shuttle… [and] a string, with a little handle called a picker… Kay's innovation was extraordinary in its simplicity…" The research lab and the corporation were very complex, and could have escaped humanity's conceptual grasp.

Laboratories and corporations had accelerants. Among the most influential was the globalization of transport, in the form of the iron-hulled screw-propellered ocean-going steamship linked to the railroad network. Another was the globalization of communication, in the form of the global submarine telegraph network linked to landlines.

Yet another was a lack of barriers. Of the consequences arising from open borders the most influential was migration—with the very important caveat that the poorest from China, India, and elsewhere were not allowed into the temperate settlements. Those were reserved for Europeans (and, sometimes, Middle Easterners). Caveat aside, a vast population of people moved; between 1870 and 1914 one in fourteen humans changed their continent.

The embrace of openness also meant the absence of government barriers to trade, investment, and communication. People could and did move, and finance, machines, railroads, steamships, and the telegraph nerves of production and distribution networks followed, chasing abundant natural, physical, and biological resources.

The laboratory, the corporation, transportation, communication, and falling barriers —together were more than enough to make the decisive watershed. They carried humanity out of Malthusian poverty in a way that the earlier British Industrial Revolution had not. And they also made the story of the world's economies one story in a way that had never been true before.

Consider the railroad.

The metallurgy to cheaply make rails and engines had made transport over land, at least wherever the rails ran, as cheap as travel up navigable watercourses or across the oceans, and made it faster.

Some groused. The mid-nineteenth century Massachusetts transcendentalist author and activist Henry David Thoreau's response to the railroad was: "get off my lawn!"

> Men have an indistinct notion that if they keep up this activity of joint stocks and spades long enough all will at length ride somewhere in next to no time and for nothing, but though a crowd rushes to the depot and the conductor shouts "All aboard!" when the smoke is blown away and the vapor condensed, it will be perceived that a few are riding, but the rest are run over—-and it will be called, and will be, "a melancholy accident."

My ancestors, and most of humanity, had a very different view.

Before the railroad, the rule-of-thumb was that you simply could not transport agricultural goods more than 100 miles by land. By that mile-marker the horses or oxen would have eaten as much as they could pull. Either you found a navigable watercourse—ideally much, much closer than 100 miles away—or you were stuck in bare self-sufficiency. Overwhelmingly, what you wore, ate, and used to pass your hours, was made within your local township, or dearly bought.

For Thoreau the fact that it took him a day to walk or ride into Boston was a benefit—part of living deliberately. But his was the point of view of a rich guy, or at least of a guy without a family to care for, and for whom Ralph Waldo Emerson's wife Lidian Jackson was willing to bake pies.

But given our global propensity to live very near navigable water, perhaps the biggest revolution in transportation came not in the 1830s with the railroad, but

later, with the iron-hulled ocean-going coal-fired steamship. In 1870 the Harland and Wolff shipyard of Belfast launched the iron-hulled steam-powered screw-propellered passenger steamship R.M.S. Oceanic. It promised to take 9 days to go from Liverpool to New York, a journey that in 1800 would have taken more like a month.

The Oceanic's crew of 150 supported 1,000 third-class passengers at a cost of £3—the rough equivalent of a month and a half's wages for an unskilled worker—and 150 first class passengers at £15 a head. In today's dollars, the same share of average income comes to $17,000. But the more relevant context is to 1870's recent past. A third class birth on the Oceanic cost half as much as passage a generation earlier and roughly a fourth as much as in 1800. After 1870 sending a member of a family across the ocean to work became a possibility open to all save the very poorest of European households.

And humans responded by the millions. The production and trade globalization of the late 1800s was fueled by 100 million people leaving their continent of origin to live and work elsewhere. Never before or since have we seen such a rapid proportional redistribution of humanity around the globe.

50 million left settled areas of Europe, mainly for the Americas and Australasia, but also to South Africa, the highland of Kenya, the black-earth western regions of the Pontic-Caspian steppe, and elsewhere. And though the redwood forests of northern California contain shrines to the Boddhisatva Guan-Yin, migration from China to European-settled California and to the rest of temperate-climate settler colonies and ex-colonies was quickly shut down. Plutocrats like Leland Stanford (the railroad baron and governor of California who founded and endowed Stanford University in memory of his son) favored immigration; the populists favored exclusion: "Chinaman go home."

In the temperate zone economies of European settlement the populists won in one narrow aspect. Until World War One, they were overwhelmingly successful in keeping the United States, Canada, Argentina, Chile, Uruguay, Australia, and New Zealand "European". The flow of migrants out of China and India was directed elsewhere, to the tea plantations of Ceylon or the rubber plantations of Malaysia. Still, fifty million Chinese and Indians migrated, going instead to South Asia, Africa, the Caribbean, and the highlands of Peru. Today we live in the distant echo of all that movement: in the late twentieth century Peru had a President surnamed Fujimori and the author V.S. Naipaul was born not in India but in the Caribbean.

Resource-rich settlement areas like Canada and Argentina with Europe-like climates provided a further boost to European living standards. The one-third who migrated and then returned home returned, in most cases, with resources that made them solid members of their home economies' middle classes. The two-thirds who migrated and stayed found their living standards and their children's higher by a factor of between 1.5 and 3. Those left behind also benefited. These decades of migration raised wages in Europe, as workers at home faced less competition for jobs and could buy cheap imports from the New World.

Plutocrat and populists alike benefited. Indeed, there is no sign that workers already on the labor-scarce western, peripheral side of the Atlantic lost out as their shores absorbed the migration wave from labor-abundant Europe. Urban American, Canadian, and Argentinian appear to have grown at 1.0, 1.7, and 1.7 percent per year in the years leading up to 1914—compared to growth rates that averaged 0.9 percent per year in northwest Europe. Only in Australia, where real wages seemed to stagnate in the half-century before 1913, does increased trade appear to have played any role in eroding the relative wages of workers in a labor-scarce economy. Regardless, migration to temperate-zone countries meant people carried capital with them, which built out the scale of the recipient economies.

Did migration lower relative wages in tropical-zone recipient economies? Yes—and it did so in economies that never saw a migrant. British capital, Brazilian-stock rubber plants, and labor imported from China to Malaya could and did put heavy downward pressure on the wages in Brazil of people who did not know there was such a place as Malaya. Economic underdevelopment was a process, something that itself developed over 1870-1914.

And migration did not raise wages much in the migration-source economies of China and India. Both had such substantial populations that emigration was a drop in the bucket.

Through ill-luck and bad government, India and China had not escaped the shells of the Malthusian Devil. Technology had advanced, but improvements in productive potential had been absorbed by rising populations, and not in rising living standards. The population of China in the late nineteenth century was three times what it had been at the start of the second millennium. So potential migrants from China and India were willing to move for what seemed to Europeans to be starvation wages.

Thus the large populations and low levels of material wealth and agricultural

productivity in China and India checked the growth of wages in any of the areas–Malaysia, Indonesia, the Caribbean, or east Africa–open to the Asian migration stream. Workers could be cheaply imported and employed at wages not that far above the physical subsistence level. Nevertheless, these workers would be very happy with their jobs: their opportunities and living standards in Malaysian or African plantations would be significantly above what they could expect if they returned to India or China. Low wage costs meant that commodities produced in countries open to Asian immigration were relatively cheap. And competition from the Malaysian rubber plantations checked growth and even pushed down wages in the Brazilian rubber plantations as well. The result: living standards and wage rates during the late nineteenth century remained low, albeit higher than in China and India, throughout the regions that were to come to be called the third world.

For ill and good the world was now an integrated unit, with one story.

Part of this global story was the emergence of a sharp division of international labor: "tropical" regions supplied rubber, coffee, sugar, vegetable oil, cotton, and other relatively low-value agricultural products to Europe. Temperate-zone regions of expanding European settlement—the United States, Canada, Australia, New Zealand, Argentina, Chile, Uruguay, the Ukraine, and perhaps South Africa—produced and shipped staple grains, meats, and wool to Europe. German farmers found themselves with new competitors, and not just from the Americas: as much came in the form of Russian grain shipped from Odessa. Western Europe paid for its imports by exporting manufactured goods. As did the northeastern United States, where industrial supplies and materials would rise to be fully half of U.S. exports by 1910.

And as wages in economies that were to become the global periphery were checked, the prospects for having a rich-enough middle class to provide demand for a strong domestic industrial sector ebbed rapidly.

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The British Empire was near-decisive. Wherever the British went they built a fort, some docks, and a botanical garden—the latter to discover what valuable plants grown elsewhere might flourish here as well. During the nineteenth century the rubber plant came to Malaysia, the tea shrub came to Ceylon, and the coffee bush came to Brazil. Rubber was not introduced into Malaysia, Indonesia, and Indochina until the last quarter of the nineteenth century. But by the end of World War I these three regions had become the principal sources of the world's natural

rubber supply. In short, the comparative advantages of the regions that were to become the periphery of the late nineteenth century global economy were not so much given as made.

The United States was the most prominent long-run beneficiary. Casting our glance, briefly, out into the future, these decades of migration also helped turned the years from 1940-2016 into an era of American predominance. Consider that in 1860 the United States had a full-citizen population—i.e., Caucasian English speakers whom the government regarded as worth educating—of 25 million, while Britain and its Dominions had a full-citizen population of 32 million. By 1940 things had changed: 117 million full-citizen Americans; 76 million full-citizens in Britain and the Dominions.

Between 1870 and 1940 were decades of technological advance, population growth and migration, and with transportation and communication a concomitant rise in trade and investment. The falling cost of transporting people marched alongside a falling cost of transporting goods: flour that cost 1.5 cents per pound in Chicago and 3.0 cents per pound in London cost only 0.5 cents per pound more after 1870. Indeed, every commodity that was neither exceptionally fragile nor spoilable could after 1870 be carried from port to port across oceans for less than it cost to move it within any country. As long as there were docks and railroads, every place in the world became cheek-by-jowl to every other place. Everyone's opportunities and constraints—not just the consumption patterns of the elite—depended on what was going on in every other piece of the world economy.

This mattered: between 1870 and 1913 exports as a share of national product doubled in India and in what was to become Indonesia, and more than tripled in China. And in Japan—forced out of two and a half centuries of Tokugawa isolationism by United States gunboats—exports rose from practically zero to 7 percent of national product in just two pre-World War I generations. In 1500 international trade as a proportion of total world production was perhaps 1.5%. By 1700 it had rising to around 3%. By 1850, about 4%. In 1880 it was 11%, and by 1913 17%. Today it is 30%.

Northwest Europe thus gained an enormous trade-relevant comparative advantage in making manufactured goods. And natural resources out on the periphery become more valuable as well: copper, coal, coffee, and all mineral and agricultural products could be shipped by rail to the ports where the iron-hulled steam-powered ocean-going cargo ships lay. The market economy responded as knowledge sped along copper wires. The industrializing core specialized in the manufactures

because of its superior access to industrial technologies. The periphery specialized in the primary products that its newly improving infrastructure allowed it to export. The ability for both to specialize was of great economic value. The social returns on the investments in technology and infrastructure that created this late nineteenth-century world economy were enormous. Consider just one example: economic historian Robert Fogel calculated that the social rate of return on the Union Pacific Railroad's trans-North American railroad was some thirty percent per year.

The growth of trade meant that the logic of comparative advantage could be deployed to its limit. Wherever there was a difference across two countries in the value of textiles relative to ironmongery—or any other two non-spoilable goods—there was profit to be made and societal well-being to be enhanced by exporting the good that was relatively cheap in your country and importing the good that was relatively dear. Once established, a comparative advantage was tended to stick for a long time. There was nothing about British-invented automated textile machinery that made it work better in Britain than elsewhere. Yet Britain's cotton textile exports rose decade after decade from 1800 to 1910, peaking at 1.1 billion pounds a year in the years before World War I.

The reach of comparative advantage was also broad. A country near-hapless in growing food but even closer to hapless in making machine tools could make itself better off by exporting food and importing machine tools. A country that was best-in-class at making automobiles but even better, in relative terms, at making airplanes could make itself better off by exporting airplanes and importing cars. It was the power of expanding world trade. Whether one's comparative advantage came from innovative entrepreneurs, a deeper community of engineering practice, a well-educated workforce, abundant natural resources, or just poverty that made your labor cheap, business could profit and society grow richer. And so the surge in real wages was worldwide, not confined to where industrial technologies were then being deployed.

This was the consequence of finance and trade following labor. The 1870-1914 world economy was a high—in historical comparative perspective—investment economy. The industrialization of western Europe and of the east and midwest of North America provided enough workmen to make the industrial products to satisfy global demands, and also to build the railways, ships, ports, cranes, telegraph lines, and other pieces of transport and communications infrastructure to make the first global economy a reality. There were 20 thousand miles of railways in the world when the U.S. Civil War ended in 1865. There were 300 thousand

miles in 1914. (There are a million miles today.)

Thus workers in Hamburg, Germany ate cheap bread made from North Dakotan or Ukrainian wheat. Investors in London financed copper mines in Montana and railroads in California. (And railroad baron Leland Stanford diverted a large tranche into his own pockets, where it became the core endowment of Stanford University.) State-funded entrepreneurs in Tokyo bought electrical machinery made by the workers of Hamburg. And the telegraph wires that connected all were made of copper from Montana and insulated by rubber gathered by Chinese workers in Malaya and Indian workers in Bengal.

The upshot? As John Maynard Keynes was to write in 1919 the upshot was that, for the globe's middle and upper classes, by 1914 "life offered, at a low cost and with the least trouble, conveniences, comforts, and amenities beyond the compass of the richest and most powerful monarchs of other ages…"

The upshot for the working classes of the globe—at least those touched by ships and railroads and thus by international commerce—was an increasing margin between living standards and bare subsistence. Malthusian forces responded: as of 1914 there were five people where there had been four a generation before. Half a century thus saw more population growth than had half a millennium back in Agrarian Age.

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Alongside transportation came communication. Around 1800 Arthur Wellesley, a fourth son of a financially-shaky Anglo-Irish aristocratic family, sought to make his fortune and reputation. Thus, the future Duke of Wellington voyaged to India. It took him seven months to get there from Britain. It took him six months to get back. That time lag meant, among other things, that whatever questions, instructions, and orders the British imperial cabinet and the directors of the East India Company asked him to convey to their proconsuls in India would be a year stale by the time they even reached Fort William in Calcutta, Fort St. George in Chennai, or Bombay Castle. A conversation where a single question-and-answer interchange takes a year is not a dialogue: it is two overlapping monologues. And conveying attitudes, practices, capabilities, and goals across such a gulf is haphazard to the point of being hazardous. The electric telegraph made things different. It connected points on the globe as messages sped through copper at nearly the speed of light.

Not everyone was welcoming. Henry David Thoreau, again, groused.

> We are in great haste to construct a magnetic telegraph from Maine to Texas, but Maine and Texas, it may be, have nothing important to communicate. [P]erchance the first news that will leak through into the broad, flapping American ear will be that the Princess Adelaide has the whooping cough…

We can hope so. Before modern public health and vaccinations, whooping cough was a vicious beast. Of the 500,000 children in any yearly age cohort in the United States in 1840, 100,000 would catch whopping cough and 10,000 would die of it—a mortality rate of 10% of those infected and of 2% of the population.

Let me be snarky: Henry David Thoreau is not making a deep point about the human urge to form ties of affection. He is not talking about how modern modes of communication disproportionally help the powerful and the rich. No, he is making a misogynistic point—that the lives of women and the children they care for are of no consequence to anyone outside their immediate family. More kindly, he is simply making a misanthropic point—that his equipoise should not be disturbed by knowledge of potential tragedies far away. Regardless, in his opinions about trains and telegraphs he wasn't just out of step with the times, he was on the wrong side of progress.

While Texas may not have had much important to learn from Maine, in the summer of 1860 Texas had a great deal to learn from Chicago: the Republican Party National Convention meeting at the Wigwam nominated Abraham Lincoln as its candidate for President. Thus started a chain of events that would kill 25,000 white adult Texans and maim 25,000 more, and would free all 200,000 enslaved African-American Texans within five years. Maine may not have had much to learn from Texas, but telegraphs reporting relative prices of Grand Bank codfish in Boston, Providence, New York, and Philadelphia were of great importance to Maine fishermen setting out.

Knowing the price of codfish is valuable, the freeing of hundreds of thousands of Americans is profound, and both only hint at the shift that came with telegraphed intelligence. Ever since the development of language one of humanity's great powers is that our drive to talk and gossip truly turns us into an anthology intelligence. What one of us in the group knows, if it is useful, pretty quickly becomes known by nearly everyone. The telegraph enlarges the relevant group from the village or township or guild to, potentially, the entire world.

Spanning the globe with telegraphs was difficult. Particularly difficult to build were the submarine telegraph cables. 1870 saw Isambard Kingdom Brunel's Great Eastern—then the largest ship ever built (nothing larger was to be built until 1901)—lay the submarine telegraph cable from Yemen to Bombay, thus completing the undersea line from London. Future Dukes of Wellington, and millions besides, no longer took months conveying news and commands from London to Bombay and back. It took only minutes. After 1870 you could find out in the morning how your investments overseas had done the previous day, and wire instructions and questions to your bankers overseas before lunch.

This mattered for three reasons.

First, this process brought not just more information with which to make decisions but also improved trust and security. Consider that 1871 saw 34-year old American financier J. Pierpont Morgan join 45-year old American financier Anthony Drexel in an investment banking partnership to guide and profit from the flow of investment funds from capital-rich Britain to resource- and land-abundant America. Today's J.P. Morgan Chase and Morgan Stanley are the children of that partnership. Second, this greatly aided technology transfer—the ability in one corner of the globe to use technologies and methods invented or in use in another corner of the globe. Third, this process was a handmaiden of empire. Where you could cheaply and reliably communicate and move goods and people you could also command and move and supply armies. Thus conquest, or at least invasion and devastation, became things that any European great power could undertake in nearly any corner of the world. And the European powers did.

Before 1870 European imperialism was—with the very notable exception of the British Raj in India—largely a matter of ports and their hinterlands, plus settler expansion into, after the plagues and genocides, the low indigenous population Americas and Australasia. By 1914 only Morocco, Ethiopia, Iran, Afghanistan, Nepal, Thailand, Tibet, China, and Japan had escaped European (or, in the case of Taiwan and Korea, Japanese) conquest or "protectorate"—and Ethiopia fell to Mussolini's Italy, with its airplanes and poison gas shells, in 1936.

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With the greatly increased speed of transmitting information, the greatly lowered cost of transporting people and the knowledge inside their heads, and the greatly lowered cost of transporting machines and the knowledge embodied in them, it seems as though, for the first time in history, it ought to have been possible to

apply any productive technology known to humanity in any corner of the world.

By the end of the 1800s that possibility seemed within reach. There were textile factories in places like Mumbai and Calcutta in India, Shanghai in China, Capetown in South Africa, and Tokyo in Japan as well as in Manchester in England, Fall River in Massachusetts, and Brussels in Belgium. The North Atlantic economic core committed resources—capital, skilled and unskilled labor, organization, and demand, the last through its need for and willingness to buy peripheral products. Before 1870 Western Europe's staple imports were limited to cotton, tobacco, sugar, and wool—with a little palm oil, furs, hides, tea, and coffee as well: luxuries, not necessities or even conveniences. After 1870 technology demanded oil for diesel and gasoline engines, nitrate for fertilizing fields, copper wiring, and rubber tires. And even without new technologies the much-richer post-1870 North Atlantic core's demand for cocoa, tea, coffee, silk, jute, palm oil, and other tropical products skyrocketed. Commodity demand and industrial technology transfer ought to have seen the world start to draw together.

It didn't.

As economist Arthur Lewis put it, the net effect of the coming of a single economic world was to enable a great many countries and regions to jump on the "escalator, taking countries to ever higher levels of output per head." Yet as of 1870 Lewis judges only six countries were fully on the escalator of modern economic growth. The first foremost desire of the Khedive of Egypt, Muhammed Ali, was to transform his country so his grandchildren would not be the puppets of French bankers and British proconsuls. Along with much else, he set out to turn Egypt into a center of textile manufacture. Except, keeping the machines working proved unachievable. His textile factories stopped. And his grandson, the Khedive Ismail, indeed became the puppet of French bankers and British proconsuls.

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It is understandable that China, India, and the other regions of what would become the post-World War II third world did not produce and export the relatively high-value commodities like wheat and wool exported by temperate settler economies: agricultural productivity was too low, and climate was unfavorable. It is understandable why–with heavy downward pressure put on wages in Malaysia, Kenya, and Colombia by migration and threatened migration from China and India–the prices of the export commodities that they did produce were and remained relatively low.

What is more puzzling is why industrialization did not spread much more rapidly to the future global south in the years before World War I. After all, the example of the North Atlantic industrial core seemed easy to follow. Inventing the technologies of the original British Industrial Revolution–steam power, spinning mills, automatic looms, iron- and steel-making, and railroad-building–had required many independent strokes of genius. But copying those technologies did not, especially when you could buy and cheaply ship industrial goods made in the same New and Old England machine shops that supplied the industries of England and of America.

If Ford could redesign production so that unskilled assembly line workers do what skilled craftsmen used to do, why couldn't Ford—or someone else—also redesign production so that it can be carried out by low wage Peruvians or Poles or Kenyans rather than by Americans, who even by 1914 were extraordinarily expensive labor by world standards?

Political risks? The advantages to being near your machine suppliers and near other factories making similar products? The need to have specialists close at hand to fix the many things that can go wrong?

It remains a great puzzle to me.

We understand far too little about why the pace of technological diffusion out of the industrial core was so slow before World War I.

"Peripheral" economies did a superb job at specializing in plantation agriculture for export. They did a bad job at creating modern manufacturing industries that could have also turned their low relative wages into a durable source of comparative advantage.

When asked why this happened, I say that Britain's (and then America's, and then Germany's) initial cost advantage was so huge that it would have required high tariffs indeed in order to nurture "infant industries" in manufacturing. I say that colonial rulers refused to let the colonized do so. I say that the ideological dominance of free trade kept many others from even considering that perhaps a Hamiltonian "developmental state" approach might benefit their economies in the long run.

But I do not claim to understand. Robert Allen thinks the dominant factor was

imperialism: colonial governments were uninterested in adopting the standard package of policy measures that would have enabled industrialization. Arthur Lewis thought that it was migration and global commodity trade: industrialization then required a prosperous domestic middle class to buy the products of the factories, and tropical economies could not develop such. Joel Mokyr thinks that it was the habits of thought and intellectual exchange developed during the European Enlightenment that was the necessary template for the required communities of engineering practice. Raul Prebisch thought that it was the dominance of landlord aristocracies notionally descended from Castilian *conquistadores* who thought their dominance over society could best be maintained if the factories that produced the luxuries they craved were kept oceans away. And I do not think I know enough to judge.

Revving the Technological Engine of Growth

The world that emerged after 1870 was globalized in a way that it had never been before. But what was "globalization"? Let us look at some arresting stories of particular individuals who took great advantage. And let us start with Herbert Hoover.

Hoover was born in 1874 in Iowa. His father was a blacksmith. He was orphaned at 10. In 1885 he started moving west—first to Oregon to live with an uncle and aunt; second to California as the first student to attend Stanford University, then free to whites of competence. (It was free to men and to women: when Herbert was a senior he met the freshman Stanford student who was to become his wife, tomboy, taxidermist, and horsewoman Lou Henry, who was then Stanford's only female geology major). Herbert studied to become a mining engineer, graduating in 1895 in the distressed aftermath of the Panic of 1893.

His first job was as a mine laborer in Grass Valley, California earning 600 dollars a year. His next was as an intern and special assistant to mining engineer Louis Janin, for which Herbert earned 2400 dollars a year. Then in 1897 he crossed the Pacific to first Australia, working for the mining company Bewick Moreing and a salary of 7000 dollars a year, and then to China, where he earned 20,000 dollars a year and up. It was in China that Hoover made his fortune.

By 1901 and up until 1917 his base was London. He worked as a consulting engineer and investor, with jobs and investments in Australia, China, Russia, Burma, Italy, and Central America in addition to the United States. In 1917 he moved back to America, where he was appointed Secretary of Commerce in 1925 and elected president in 1928. From son of the town blacksmith to college graduate to multimillionaire mining consultant to elected President of the United States in 1928—was anyone else's ascent so far and so fast even in America?

However, the crisscrossing of talent, technology, information, and money that was globalization was not even most of the watershed of 1870. Every year between 1870 and 1913 the speed with which newer and better technologies and organizations evolved and were deployed was more than quadruple what had been before 1870: 2.1%/year, globally, rather than 0.45%/year. Among the global

economic leaders—initially America, Germany, and Britain, with Britain rapidly falling off—the speed with which which newer and better technologies and organizations were evolved and deployed at twice as rapid a relative pace as before 1870.

Before 1870, inventions and innovations had by and large been singular discoveries and adaptations. They produced new and better ways of doing old things: of making thread, of weaving cloth, of carrying goods about, of making iron, of raising coal, and of growing wheat and rice and corn., Having come up with these improvements, their inventors then sat down to develop and exploit the benefits of their inventions. They It was a process that thus required inventors to be not just researchers but development engineers, maintenance technicians, human-resource managers, bosses, cheerleaders, marketers, impresarios, and financiers as well.

That pre-1870 system was good enough as long as the conjuncture of circumstances was just right. Consider, the steam engine of the eighteenth century. It needed a cheap source of fuel, it needed something important and profitable to do, and it needed societal competence at the metalworking technological frontier. Fuel was found at the bottom of the coal mines. With the steam engine, cheap plantation-grown cotton ideally suited for machine spinning, quickly reached factories that produced sought after goods. And with practical metallurgy to make iron rails and iron wheels cheaply, the fuse that was the Industrial Revolution was lit. Steam power propelled the automatic spindles, looms, metal presses, and railroad locomotives of the nineteenth century.

But the fuse might well have sputtered out. That, after all, is what previous pre-1870 history would have led one to expect. Printing, the windmill, the musket, the seagoing caravel, the watermill, and before it the horse collar, the heavy plow, the legion, the olive press, and so forth had each sputtered out before they lit the rocket of modern economic growth. Each of these did revolutionize a piece of the economies of their day.

Yet none of them lit anything like the rocket we have ridden since 1870. Ancient Mediterranean civilization was followed by what is rightly called a Dark Age. The horse collar and the heavy plow shifted the center of European settlement and commerce northward but did not bring Europe closer to utopia. And Gunpowder Empires and even Steampunk World are desperately poor societies under the spell of the Devil of Malthus, which we are not.

What had changed?

What changed, what made the third and the crucial post-1500 watershed, is that as of 1870 the leading edge North Atlantic economies had *invented invention*. They had not just invented textile machinery, railroads, and the company. They had invented the industrial research lab. But that is not all. The leading edge North Atlantic economies also invented bureaucracy in the form of the large corporation. Thereafter, what was invented in the industrial research labs could then be deployed at national or continental scale. And finally they invented the idea that there was a great deal of money to be made and satisfaction to be earned by inventing not just better ways of making old things, but in making brand-new things.

Not just inventions, but the systematic invention of how to invent. Not just individual large-scale organizations, but organizing how to organize. Both were essential to what were not decentralized systems of exchange, but the arrival of the integrated, command-and-control central planning of large islands of the world's market economies that are modern corporations. Every year between 1870 and 1913 the newer and better industrial technologies that emerged from the first industrial research laboratories were deployed, sometimes as they were sold to already established producers, but more as they spurred the build-out of the large corporations with professional managements that emerged at the start of the long twentieth century.

As economist W. Arthur Lewis observed, a rich man in 1870 possessed the same things that a rich man in 1770 possessed. A century on, the rich might well have had more of those things—more houses, more clothes, more horses and carriages, more furniture. But displaying wealth was a matter of displaying the number of servants one employed, rather than the commodities one personally enjoyed. After 1870s, that changed. The making of new commodities added a new twist, granting the rich access to, as Lewis put it, "telephones, gramophones, typewriters, cameras, automobiles, and so on, a seemingly endless process whose latest twentieth-century additions include æroplanes, radios, refrigerators, washing machines, television sets, and pleasure boats."

These are often called a "second industrial revolution," but that misses much of the point. It was not so much the arrival of any particular technology, as it was ever more individuals grasping the fact that there was a broad and deep range of new technologies to be discovered. And that too was not entirely sufficient. For it was the industrial research labs and large-scale corporate organizations that could and

did plan the invention and deployment of Lewis's list of wonders, and then some.

Consider steel. What would be the fundamental building material of the twentieth century and the master metal of industrial civilization was effectively invented anew in the second half of the 1800s. Steel is iron mixed with carbon, with between ninety and ninety-nine out of every one hundred atoms an iron atom. You can make carbon-free wrought iron in your furnace if you keep its temperature below the melting point of iron and hammer it as the slag, or the various impurities in the iron, melt and run out, and then do this over and over again. But wrought iron is too soft for industrial purposes. If you heat your furnace with coke, a pure form of coal, and keep it high enough to melt the iron the carbon from the coke alloys with it and you get pig or cast iron. But it is too brittle for industrial purposes.

Steel is just right—but getting it "just right" is not easy.

For thousands of years steel was made by skilled craftsmen heating and hammering wrought iron in the presence of charcoal and then quenching it in water or oil. In the centuries before the nineteenth making high-quality steel was a process limited to the most-skilled blacksmiths of Edo or Damascus or Milan or Birmingham. It seemed, to outsiders—and often to insiders—magic. In the Germanic legends as modernized in Wagner's opera *Das Rheingold*, the doomed hero Siegfried acquires a sword made by a skilled smith. But its maker, the Dwarf Alberich, is in no respect a materials-science engineer. Alberich is a magician.

That changed in 1855-6 when Henry Bessemer and Robert Mushet developed the Bessemer-Muchet process. It forced air through the molten cast iron to burn off all non-iron impurities, and then added back just enough carbon (and manganese) to make the steel needed for industry. The price of ton of steel dropped by a factor of seven, from £45 down to £6 at a time when £70 per year was the average wage in Britain. The Thomas-Gilchrist and Siemens-Martin processes rapidly followed. Worldwide steel production would rise from trivial amounts—enough for swords, and some cutlery, and a few tools that needed the sharpest attainable edge—with cast iron being the main metallic structural material to some 70 million tons a year by 1913, and would grow to 170 million tons by 1950—and 1500 million tons a year as of 2020. As I write, steel costs about $500 per ton at a time when the average North Atlantic full-time wage is nearly $50,000 per year.

But it was not just steel. As Northwestern economic professor Robert Gordon wrote, the year 1870 was the dawn, for over the next several decades:

> every aspect of life experienced a revolution. By 1929, urban America… electrified… networked,… with electricity, natural gas, telephone, clean running water, and seers... the horse had almost vanished from urban streets… the ratio of motor vehicles to the number of households reached 90 percent… the household… enjoy[ed] entertainment[s]… beyond the 1870 imagination…

Much of this came long before 1929. And it was by nowise confined to the United States. On the 1889 centennial of the storming of the Bastille during the Great French Revolution, France held a universal exposition. At the center of it was not some tableau of revolutionary martyrs, but a tower designed by and named after Gustave Eiffel. As historian Donald Sassoon writes, the French exposition became a: "consecrat[ion of]… commerce and trade, modernity, and the wonders of technology exhibited in the Galerie des Machines… Under the banner of modernity, progress, and the peaceful pursuit of wealth, the French people would regain national pride and unity…" And it its heart was Eiffel's tower, which has dominated the Paris skyline every since, and is constructed of that wondrous modern material, steel.

* * * *

Across the Atlantic Ocean from Paris, in New York's harbor, was another steel-free product of Gustave Eiffel. But the steel framework was clothed in copper, and called the Statue of Liberty.

Life was still hard and dirty. America, rapidly becoming the world's growth poll as the year 1900 passed, was still poor. And it was very unequal. Indeed, but for those Americans held in bondage just a few decades earlier, it was more unequal than it had ever been before, or than it would ever be again until 2020. Yet America the in the decade of the 1900s was also a very attractive place compared to every single other place in the rest of the world. In spite of the hours, in spite of the risk of death or injury at the hands of corporations that did not regard worker safety as job #1 or even job #10, American jobs were very good jobs by international standards. They were jobs worth moving 5,000 miles for, from Hungary or Lithuania to suburban Pittsburgh or New Jersey, for that was where the technologies were being applied. By common agreement, America was exceptional.

It is traditional at this point in any history of the Second Industrial Revolution to talk about Thomas Alva Edison. The most famous inventor in the world, "the wizard of Menlo Park," New Jersey, who would register more than 1000 patents

and found 15 companies, including what is now called General Electric. But Edison's story is too well-known.

Let's talk instead about another migrant who, like Herbert Hoover, moved west—but not from Iowa to Oregon and California to Australia and China to London. Let's talk about someone who moved from Croatia to America. And let's talk about someone who ended up not a multimillionaire ex-president and respected Republican elder. Let's talk about somebody who ended up a penniless charity case, living in midtown Manhattan without any roof of his own: Nicola Tesla.

Tesla was born on July 10, 1856 in the town of Smiljan, in the Krajina region of the province of Croatia, in the Habsburg empire then reigned over by the young Emperor Franz Josef in Vienna. He was the fourth of five children. His father was literate—a priest in the Serbian Orthodox Church—but his mother was not. His parents wanted him to become a priest. He wanted to become an electrical engineer.

Tesla studied electrical engineering in Graz, Austria for two years, and then dropped out of school. He broke off relations with his family and friends, worked as an engineer for two years, and apparently suffered a nervous breakdown. His father urged him to return to college at Prague's Karl-Ferdinand University. Perhaps Nikola did, but if so only for one summer. Around which time his father died.

1881 finds Nikola Tesla working in Budapest for a startup, the National Telephone Company of Hungary, as chief electrician and chief engineer. But he does not stay. 1882 sees him in Paris working as an improver and adapter of American technology. And on June 6, 1884 the brilliant but highly eccentric Tesla arrived in New York with nothing in his pockets save a letter of recommendation from engineer Charles Batchelor to Thomas Edison: "I know of two great men," Batchelor had written. "You are one of them. This young man is the other." And so Edison hired Tesla.

In America Tesla went to work for Edison Machine Works. He would later claim that Edison promised him $50,000—the entire net worth at the time of the Edison Machine Works—to improve and redesign Edison's direct current generators. Whatever was or wasn't agreed to, in 1885 Edison refused to pay that sum. Tesla quit and found himself digging ditches for a living for a couple of years.

By his own estimations, Tesla was a difficult man. The day after Edison died, for

example, Tesla sketched for the newspapers his one-time employer and world-renowned inventor thusly: Edison

> had no hobby, cared for no sort of amusement of any kind and lived in utter disregard of the most elementary rules of hygiene .... His method was inefficient in the extreme, for an immense ground had to be covered to get anything at all unless blind chance intervened and, at first, I was almost a sorry witness of his doings, knowing that just a little theory and calculation would have saved him 90 percent of the labor. But he had a veritable contempt for book learning and mathematical knowledge, trusting himself entirely to his inventor's instinct and practical American sense…

Of his own personality, Tesla wrote:

> I had a violent aversion against the earrings of women… bracelets pleased me more or less according to design. The sight of a pearl would almost give me a fit but I was fascinated with the glitter of crystals… I would get a fever by looking at a peach… I counted the steps in my walks and calculated the cubical contents of soup plates, coffee cups and pieces of food—otherwise my meal was unenjoyable. All repeated acts or operations I performed had to be divisible by three and if I missed I felt impelled to do it all over again, even if it took hours…

Tesla coupled his eccentricities with bizarre and utopian claims about the future course of science and technology. He was, as much as Mary Wollstonecraft Shelley's fictional Dr. Viktor von Frankenstein, the very model of the mad scientist. Thus he found it difficult to maintain either financial backers or a supporting engineering staff.

Yet Tesla and his allies beat Thomas Alva Edison and his in the struggle over whether electricity was going to be AC or DC. And in 1894 Tesla's was the first, or at least one of the first, demonstrations of radio. And our entire electrical power grid and everything that draws off of it--our electric appliances and engines, based as they are on alternating-current generators, polyphase systems and long-distance transmission through high-voltage power lines--are Tesla's much more than they are Thomas Edison's. The world from space at night, illuminated by the electric power grid, is Tesla's world.

How could the mad scientist Tesla make such a difference? Because he could work in *industrial research labs* and his ideas could be developed and applied by corporations. He could work for George Westinghouse. And General Electric could copy what he had done.

Tesla was first, foremost, and finally an inventor. 1887 saw Tesla as the proprietor of Tesla Electric Light and Manufacturing, but his financial backers fired him from his own company. 1888 saw Tesla demonstrating an alternating-current induction motor—the ancestor of all our current alternating-current motors—at the American Institute of Electrical Engineers meeting. 1889 saw Tesla with a permanent financial backer, Westinghouse.

That was the year Tesla began working at the Westinghouse Electric and Manufacturing Company's laboratory in Pittsburg. In 1891, at the age of 35, Tesla was back in New York establishing his own laboratory, which the sale of his patents to Westinghouse under a patent-sharing agreement made possible. In 1892 he became vice president of the American Institute of Electrical Engineers and received his patents for the polyphase alternating-current electric power system. And in 1893 Nikola Tesla and George Westinghouse used alternating-current power to illuminate the Chicago's World Fair—the first World Fair ever to have a building for electricity and its applications.

The late 1880s and 1890s saw Westinghouse and Tesla and their backers struggle against Edison and his backers in the so-called "war of the currents." Edison had bet on a direct current—DC—electrical grid. Direct current worked very well with incandescent lamps and with the motors of the day. Direct current worked well with storage batteries, which meant that you only had to build the expensive generating capacity for average loads rather than peak loads. And Edison had not understood what Tesla was getting at when Tesla worked for him: "[Tesla's] ideas are splendid, but they are utterly impractical…"

The alternating current—AC—systems of Tesla and Westinghouse allowed the efficient transmission of electric power over long distances through very high-voltage power lines. Once the energy got where you want it to go, it could then be reduced, via step-down transformers, to a voltage that wasn't immediately fatal. (But you had to be very careful: once a contractor drilling a hole in the garage wall of my house drilled into a 44,000 volt line because the transformer had been placed in our basement rather than out in the street: he was very lucky, and survived without major injury.) There was no equivalent trick (and risk) for Edison's direct-current system, which required low voltage be pushed across long distances, incurring extremely large resistance power losses. On the other hand, it was not obvious how alternating current could be used to power anything useful. Until, that is, Tesla invented the induction motor.

Both Westinghouse and Edison nearly bankrupted themselves as each struggled to build out an electrical power grid fast enough to become the dominant standard. Westinghouse and Tesla won—although ConEd still had 4600 DC customers in New York as of 1998.

Tesla the mercurial inventor the reach of whose ideas was vastly expanded by the wealth and organizational intelligence of others reached their end after Tesla, in 1899, moved from New York to Colorado Springs to conduct experiments in high-voltage power distribution—both through wires and wireless. His wireless power distribution experiments soon turned into radio, an outcome in which he had limited interest.. Tesla was instead captivated with the idea of distributing electric power throughout the world without having to build power lines, and in distributing electric power for free. His was a kind of open-source electric power movement that antedated the open-source software movement by ninety years.

The Italian inventor Guglielmo Marconi and his backers were to win the patents over radio and much of the consequent profit—at least until World War I when the U.S. Navy seized all radio intellectual property as of vital importance for national security.

Dominant financier J.P. Morgan backed Tesla, directly and indirectly, for a long while. But then in 1907 he decided that the heroic age of electricity was over. It was time, Morgan decided, to rationalize operations and replace the visionary inventors like Tesla and the executives like George Westinghouse who could deal with them with managers who would routinize the business, and focus on the bottom line.

Another world war later, the United States Supreme Court would award Tesla with the radio patents, perhaps with the understanding that he was less likely to make trouble over them than would Marconi's heirs. It mattered little to Tesla, who died penniless in 1943, a charity case protected from the world by the grace of the management of the Waldorf-Astoria hotel in New York City.

* * * *

Telsa was not alone in straddling the end of the short 19th century and the start of the long 20th. As a creative, inventive genius he kept rare company; in his impoverishment he kept vast company. The world of 1870-1913 was still, by our standards, a very poor world.

In 1870 nearly all humans still earned their bread by the sweat of their brow expended tilling the earth. Most humans could not read, had not seen a steam engine up close, had not travelled in a railway train, had not spoken on a telephone, or lived in a city. For most human beings life expectancy was little higher than it had been since the neolithic revolution nearly 12,000 years ago. And in the United States, even on the eve of World War I, still saw more than one out of three Americans at work in agriculture. Recall that at the time, the United States was a beacon to the world's toiling millions willing to move continents to improve their lots. Of all the countries of the world, only Britain and Belgium were moving their labor forces out of agriculture and into the cities significantly faster than America was doing.

The world's relative poverty is visible in disparate measures. Consider that worldwide in 1870 five ounces of copper was mind per person; by 2020 we mine five pounds per person. In 1870 one pound of steel was produced per person in the world; by 2020 we produce 350. Or, consider that at the start of the twentieth century Germany was the world's third superpower, more powerful and more industrialized than any other nation save Britain and the United States. But when Adolf Hitler's Nazi Germany went to war in 1939, four-fifths of the wheeled and tracked vehicles in his army were powered by horses. And mules.

The world of 1870-1913 was indeed a very poor world when judged by our standards. Not, however, by those of prior generations. The growl that accompanied Thomas Malthus's Devil was the growl of empty stomachs, and in 1870 the daily wages of an unskilled worker in London bought him (not her: women were paid less) about 5,000 calories worth of white bread—5,000 calories, or about 2 ½ times what you need to live (you could buy more calories if you were willing to eat whole wheat bread, and even more if you were willing to eat oats). In 1800 his daily wages would have bought him about 3,500 calories, and in 1600 2,500 calories. Let us instead now look forward in time. From 1870 look out another 140 years and daily wages for an unskilled worker in the North Atlantic buys 10,000 white-bread calories per day. By 2020 the daily wages of an unskilled worker in London buys him or her 2,400,000 calories. Count those zeros: not thousands of calories, but millions.

That 5,000 calories compared to today's 2.4 million calories is the most important fact to grasp about the world economy of 1870-1913. The economy then belonged, even for the richest countries, much more to its past, the world of the Middle Ages, than to its future of—well, of us. And the same, except possibly for the rich and the upper, upper middle classes of the world economy's industrial core, was still true in

1913.

Consider Professor G.H.M.

In 1902 this anonymous college professor wrote a four-page article for the *Atlantic Monthly* in which he claimed to be vastly underpaid. With pique he wrote, the "average college professor's salary"—the salary that he saw as clearly inadequate and unfairly low—"is about $2,000." Yet at the time $2,000 per annum was four times the average national income per worker. For comparison's sake, in 2020 a professor earning four times the national average would command an annual academic salary of $600,000.

But G.H.M. saw himself as a "reasonable man". He did not ask for "a large salar[y], commensurate with what equal ability would bring in other lines of work ($10,000 to $50,000)"—or 20 to 100 times the then-current average national income per worker.

Yet the *Atlantic Monthly* did not give this ordinary professor four pages for parody. As G.H.M. went through his budget, readers nodded that his family is indeed strapped for cash. The first large expense he listed was for personal services. With no consumer durables—refrigerators, washers and dryers, oven ranges powered by electric grid or municipal gas, not to mention cars and home appliances--"we must pay $25 a month for even a passable servant." Add to that $10 a month for laundry, for the regular "servants will do no laundry work," he complained. And then $1 a month in nominal terms for haircuts, and $2 a month in nominal terms for a gardener. On personal services alone we are up to $445 a year—roughly the average nominal level of U.S. GDP per worker in 1900. And the individuals hired to help did so without benefit of a gasoline-powered lawnmower, electric hedge clippers, a vacuum cleaner or dishwasher..

Professor G.H.M. could not afford to live within walking distance of campus, could not afford to keep a horse and carriage, and so had to use that newfangled high-tech invention—the bicycle—to commute. That an ordinary professor could feel, along with a reading public, that his talents should command such an enormous multiple of the average income is a sign of how unequal an economy and society the turn of the twentieth century U.S. was.

That inequality comes into sharp relief when we cease worrying about this average professor and worry instead about the average working-class family at the start of the twentieth century.

Consider that a third of American households in 1900 had boarders, almost always male and unrelated, sleeping and eating in the house. It was the only way for the housewife to bring income directly into the household. It also multiplied the amount of labor she had to do. Much of it was manual. For example, few households had running water or a hot water heater. Instead, water came in by the bucket from a common faucet that was, hopefully, near the house, and for washing it was then heated on the stove. The same absence of durable goods that cursed our professor damned our housewife, from heating that stove to cleaning a shirt.

The—relatively prosperous for its time—factory steel town of Homestead, Pennsylvania further makes the point.

There only one in six working class households had indoor bathrooms in 1910. Half of "Slav" and "Negro" families lived in one or two room houses. Most white families lived in four room houses—and "Slavs" and "Latins" and "Hebrews" were not white. But even in the relative comfort of a four-room house, few could afford to heat more than one room through a Pennsylvania winter, And how many ways can you think of to cook potatoes on cast-iron stoves heated by coal and wood? Meal preparation was not a one-hour-a-day but a four-hour-a-day task.

Those who could afford the resources to maintain bourgeois styles of cleanliness flaunted it. White shirts, white dresses, white gloves were all powerful indications of wealth in turn of the century America. They said, "I don't have to do my own laundry," and they said it loudly.

Infant mortality was high. One in five babies in Homestead, Pennsylvania died before reaching his or her first birthday. Adult women faced substantial risks in childbirth. And adult men died, too, like flies. Accident rates in the factory left 260 injured per year and 30 dead. This out of a total population of 25,000 and a steel mill working population of 5,000. Each year, five percent of that 5,000 were injured sufficiently to miss work, one percent were permanently disabled, and half a percent were killed in factory accidents.

Start to work for U.S. Steel when you are 20. There is one chance in seven that the factory will kill you before you reach 50, and almost one chance in three that the factory will disable you. Is it any wonder that life insurance and disability insurance provided by local lodges and organizations (because the company provides few)—loom so large in American working class consciousness at the turn of the century? Is it any wonder that Homestead was home to some of the most

violent and brutal labor disputes of the late 1800s century, exceeded in viciousness only by the mines of the Rocky Mountains and the railroad marshaling yards of Chicago? And is it any wonder that the first component of the welfare state put into place in many parts of the United States was workmen's compensation?

Most of the Homestead workforce only worked six days a week. That "only" was hard won, for U.S. Steel viewed shutting most of the mill on Sundays as a major concession on their part, a concession that they hoped would produce large public relations benefits. As long as it could find workers willing to work the night shift, the Homestead mill (depressions and recessions apart) stayed open 24 hours a day on weekdays. And when things did change, they changed all at once-from two 12-hour shifts before and during World War I, to two (or three) 8-hour shifts during the 1920s, and during and after World War II.

Yet Homestead jobs—at least Homestead jobs taken by native-born Americans—were good jobs for the time, even by the elevated standards of the United States. Most who held those jobs were grateful. "Their expectations were not ours," historian Ray Ginger explains. "A man who grew up on a Southern farm did not think it cruel that his sons had to work as bobbin boys [collecting spun thread in a textile mill]. An immigrant living in a tenement and working in a sweatshop yet knew that for the first time in his life he was wearing shoes seven days a week." White households could make around 900 of 1910's dollars a year, which placed them well within the upper third of the U.S. population in terms of income per household, in the richest country in the world save for Australia.

Relative to what could be earned by people of similar skill levels anywhere else in the world, a job in the Homestead mill was a very attractive job. And so people came to America, and people in America sought out the places like Homestead where the economy bustled.

* * * *

The sources of America's exceptional wealth were many.

By 1870 the focus of economic growth crossed the Atlantic from Britain to America, where continent-wide scale, a flood of immigration, vast resources, and an open society made inventors and entrepreneurs cultural heroes.

Some have noted that the scale of the country induced industries that could take advantage of the potential demand created by a continent-wide market to embrace

mass production and with it modern management. Some note the great tide of immigrants that turned to America, bringing with them, as we noted in the last chapter, labor, talent, and a willingness to work and consume. Still others have stressed the crucial role played by natural resources in America's industrial supremacy: in a world in which transport costs were still significant, a comparative advantage in natural resources became a comparative advantage in manufacturing. Others stress the links between a resource-rich economy and the "American system" of manufactures, relying on standardization, attempts to make interchangeable parts, heavy use of machinery—and wasteful use of natural resources like materials and energy. Still others stress the openness of American society, the ease with which individuals, ideas, capital, and initiative moved across the continent, across continents, and back again.

It was a system of opportunities in which a Hoover and a Tesla, not to mention a Westinghouse an Edison a Professor G.H.M. and a Homestead laborer could feel and be ambitious. But calling it a system is too grandiose, suggesting some far-sighted process. In the twentieth century these collective sources of exceptional wealth lead to the possibilities of mass production not because of any deliberative, planned process of industrial development but through myopic choices that generate further technological externalities. The invention of inventing, it turns out, produces yet more inventions.

To which we can add two additional sources of American wealth: education and (save for the Amerindians, then being herded onto reservations, and for African-Americans, against whom white society was then waging a low-level guerrilla-terrorist war to keep them in their place) peace.

In America in 1913, even in rural America, children went to school. The years before World War I saw a large increase in education, as at least elementary school became the rule for children in leading-edge economies. And the number of years of education enjoyed on average grew as well.

In countries like the United States that made the creation of a literate, numerate citizenry a high priority. And that encouraged those with richer backgrounds, better preparations, and quicker or better trained minds to go on to ever higher education. Industrialists and others soon found the higher quality of their workforce more than making up for the taxes levied to support mass secondary and higher education.

It was not a unique American advantage. While the United States' edge in education was a powerful factor in giving the United States an edge in productivity,

Germany's edge in education was a powerful factor in giving Germany an edge in industrial competitiveness also. In the United States in 1910 some 355,000 were attending college, making up nearly five percent of their age cohort. In Germany in 1910 some 1,000,000 students were enrolled in post-elementary education.

The British Empire took notice of the growing colossus across the ocean to the west. It drew the rising superpower closer to it by strengthening all kinds of ties. economic, cultural, social, and familial.

Consider Jennie Jerome, daughter of New York financier Leonard Jerome, who made a reverse migration: from Brooklyn to Westminster. The occasion was her marriage to Lord Randolph Spencer-Churchill. The couple became engaged in 1873 just three days after their first meeting at a sailing regatta off the Isle of Wight. Their marriage was then delayed seven months while Jennie's father and the groom's father, John Winston, the seventh Duke of Marlborough, argued over how much money she would bring to the marriage and how it would be safeguarded. Randolph died two decades later, and thereafter Jennie was "much admired by the Prince of Wales", as they put it in those days, before she married George Cornwallis-West, who was a month older than Jennie and Randolph's son Winston.

Jennie and Randolph's son Winston Leonard Spencer Churchill (1874-1965) was born eight months after their marriage. He would be the *enfant terrible of* British politics when young, a disastrous British Chancellor the Exchequer—the equivalent of Finance Minister or Treasury Secretary—when middle-aged, and a decisive factor in defeating the Nazis as British Prime Minister during World War II. And not least of Winston's excellences as a wartime prime minister was that he was half American.

The end result of all these factors was a United States that had a remarkable degree of technological and industrial dominance over the rest of the world for much of the twentieth century. It also captured much of the world's imagination.

Because it was in relative terms so prosperous, and because its gradient of technological advance in the pre-WWI period was so much faster than that of western Europe, the United States was the country people looked to see the shape of the future throughout the twentieth century. In the seventeenth century much of Europe had looked to Holland; in the nineteenth century much of the world had looked to Britain. As the long twentieth century began, almost the entirety of the world and all of Europe looked to America. To observers it appeared to be a

qualitatively different civilization. The United States lacked the burden of the past that constrained the politics and oppressed the peoples of the nations of Europe, and, freed from the burden of the past, it could look unreservedly toward the future.

The American advantage was greatly reinforced by the fact that in the United States the Belle Époque, the Gilded Age, the economic El Dorado, the period of explosive prosperity set in motion around 1870 lasted without interruption longer than elsewhere in the world. China collapsed into revolution in 1911. Europe descended into the hell of World War I in 1914. In America the period of progress and industrial development lasted longer—from when the guns fell silent at the end of America's Civil War at Appomattox in 1865 until the start of the Great Depression in the summer of 1929.

We can see some of the admiration and wonder that turn of the century America triggered by gazing at the early twentieth century United States through the eyes of yet another migrant: Lev Davidovich Bronstein.

Not only Lev but his father David (1847–1922) and mother Anna (1850-1910) had been migrants. David and Anna crossed the greatest river they had ever seen to move hundreds of miles out of the forest and into the grasslands—lands where the horse nomads had roamed within recent historical memory before their suppression by the army. There they lived on what were among the richest agriculture soils in the world, and very thinly settled. It was fifteen miles from the Bronstein's farm to the nearest post office.

But this is not Laura Ingalls Wilder's *Little House on the Prairie,* a story of the European settlement of the wheatlands of America. The Bronstein's farm was in in Yanovka, in the Ukraine. The languages they spoke were Russian and Yiddish, not English. When they sent their son Lev to school by sending him to the nearest big city, it was not the Lake Michigan port city of Chicago, but the Black Sea port city of Odessa.

There he became a communist. And midway through his career he found himself feared by Czars and policemen, and hunted and exiled because he was feared. Unlike the bulk of the people who had left the Old World for the New and wound up in New York in the 1910s, the communist Lev did not want to be there. But he and his family made the best of it. The Bronsteins:

> rented an apartment in a workers' district, and furnished it on the installment plan.

> That apartment, at eighteen dollars a month, was equipped with all sorts of conveniences that we Europeans were quite unused to: electric lights, gas cooking-range, bath, telephone, automatic service-elevator, and even a chute for the garbage.These things completely won the boys over to New York. For a time the telephone was their main interest; we had not had this mysterious instrument either in Vienna or Paris...

They—particularly the children—were overwhelmed by the prosperity of the United States, and by the technological marvels that they saw in everyday use:

> ...the children had new friends. The closest was the chauffeur of Dr. M. The doctor's wife took my wife and the boys out driving... the chauffeur was a magician, a titan, a superman! With a wave of his hand, he made the machine obey his slightest command. To sit beside him was the supreme delight...

Lev stayed in the United States for less than a year. The Russian Revolution came, and he returned to the city of St. Petersburg. It was a city that would change its name several times over the long twentieth century, first to Petrograd, than to Leningrad, and recently back to St. Petersburg. Fittingly, Lev would change his name, too. He took an alias from one of his former Czarist jailers in Odessa: Lev Bronstein became Leon Trotsky.

He was never allowed back into the United States. Trotsky was, after all, a dangerous subversive, with a long-run plan that included the overthrow of the government of the United States by force and violence. He became Lenin's right-hand, the organizer of Bolshevik victory in the Civil War, the first of the losers to Stalin in the subsequent power struggle, and finally the victim of the Soviet secret police, assassinated with an ice-pick in his head outside Mexico City in 1940.

Before his murder, while in exile, Trotsky would recall his departure from New York City. And in doing so he would capture what much of the world believed. In leaving New York for Europe, Trotsky felt, he was leaving the future for the past:

> I was leaving for Europe, with the feeling of a man who has had only a peek into the furnace where the future is being forged…