Secular Stagnation: History and Reality

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ABSTRACT

Is secular stagnation a real concern? We should start with the observation that in the long run secular stagnation has been historically the "normal" situation. Most economies of the past "stagnated" in the sense that their growth rates were zero or negligible; growth has become the norm only in the past two centuries in the West, and for an even shorter period in Asia and elsewhere. In asking the question whether it would be possible that the clock be turned back and return to the stagnation of the past, we need to ask why sustained growth was absent through most of human history and what factors were responsible for the phase transition that turned the world from a stationary (stagnant) state to one of sustained growth. I isolate three factors: population dynamics, rent-seeking, and limitations on human knowledge. All three of those are no longer in force. Long-run (secular) stagnation is therefore highly unlikely even if measured GDP growth rates may fluctuate. Yet this prediction is contingent on institutional and political factors being aligned with technological progress, which is becoming increasingly questionable.

Introduction

Modern economic growth, or as Deirdre McCloskey has termed it "the Great Enrichment," has been relatively recent phenomenon. If recorded human history is approximately 6,000 years long, sustained growth that doubled income every generation or so has been experienced for at most three percent of human history, the other 97 percent being stagnant. Of course, few people before the Industrial Revolution complained about "secular stagnation" — practically nobody imagined that economic growth and continuous progress in the material conditions of life were at all possible. Whatever progress there was in one year would melt away subseuently, and a random individual born on this planet at the time of Napoleon would not be significantly richer than a random individual born at the time of Nebuchadnezzar.[1] In that sense, secular stagnation would be a return to normal.

But what was normal for most of human history is not normal in the twentieth and twenty-first centuries. Growth has been the norm in the more recent past, despite colossal disruptions in the political arena leading to two global wars, a wave of totalitarian regimes, repeated occurrences of genocide, a nuclear arms race, and other assorted disasters. In what follows, I will explain in which ways the modern era was different from everything that came before, and that will give us a unique perspective on assessing what the chances are that the conditions of the past will return. Needless to say, all such assessments need to phrased in the conditional and subjunctive modes, since the entire point of this essay is to argue that we are still in the midst of a phase transition in economic

[1] For powerful, if somewhat overstated descriptions of this absence of growth, see Clark (2007) and Galor (2011). There were some exceptions to that rule in northwest Europe and Italy, where growth had already raised living standards significantly by 1800, but even that growth had been slow and uneven, and they affected a tiny part of humanity.

history, and that hence all bets are off. But some scenarios can still be assigned a low probability.

The Malthusian Curse

The most widely cited explanation for why growth could not take place in the past is population dynamics. The idea was famously enunciated by Malthus and has since carried its name, although it was perhaps most eloquently expressed by H.G. Wells (1923, p. 68): humanity "spent the great gifts of science as rapidly as it got them in a mere insensate multiplication of the common life." The argument is known to every economist. Under some fairly reasonable assumptions, any rise in income per capita or productivity, whether derived from the "great gifts of science" or any other source, will lead to a decline in deaths and a rise in births, and as population growth sets in, diminishing returns to a fixed factor such as land or more generally the environment will set in, and income will decline (Clark, 2007; Galor, 2011; Ashraf and Galor, 2011). This kind of demographic negative feedback explains why in the very long run any improvement in the human condition was quite ineffectual and the only indicator of technological progress in the very long run is population size (Kremer, 1993).

Whether the classical "iron law" is a good description of historical reality remains to be seen; some parts of it have been confirmed using historical data (Kelly and Ó Gráda, 2012, 2014), but it is also clear that the stark implications of the fundamentalist Malthusian position are a simplification of history (Voth and Voigtlaender, 2013a, 2013b). Either way, there is a general consensus that the Malthusian model had ceased to be a good description of the world at just about the time of the writing of Malthus's famous book, and that the stagnation it implied no longer held in the second half of the eighteenth century, when demographic growth took off in most parts of Europe.

The three basic assumptions that it rested on have been undone. The first is that birth rates rise with income — both on a global and on an intra-national level, the correlation is reversed. The richer a nation, or a person, the lower their fertility tends to be. The reasons for this dramatic reversal in human reproductive behavior have been discussed at great length, and there is no need to repeat those debates here in detail here. Four factors stand out, all of them the direct consequence of economic modernization in some form: the wide availability of inexpensive means of effective fertility control; the desire to have higher quality children at the expense of quantity; the many substitutes that have emerged for children in their various economic and social functions; and the decline of religion in much of the secular and humanistic West. The fact remains that in the richest part of the world, Europe, fertility rates are now below replacement levels in *every* nation (with the exception of France), and that in North America, both the United States and Canada are now in the same situation.

The second assumption of the Malthusian story, that mortality rates will decline with income, is less clearly refuted. Rich countries or people still have lower mortality rates. But that curve is flattening out, and for a large range of incomes a negative correlation between income and mortality rates is not observable.[2] Malthusian "positive checks" (famines, epidemics and wars that would reduce population if income was too low) have by and large disappeared from most of the world, and when famines occurred in the twentieth century, they have tended to be entirely man-made and *not*

[2]Simple regressions of mortality rates on log GDP per capita on 168 nations still show a significant negative coefficient. However, once we limit the sample to the 60 top countries, the significance vanishes and the adjusted R-square is essentially zero.

the result of overpopulation (Ó Gráda, 2015; Alfani and Ó Gráda, 2017).[3] Spikes in mortality that in the pre-industrial past were correlated with poor harvests and/or the outbreaks of epidemics and have been seen as Malthusian responses to population pressure, have more or less disappeared in most of the world.

The third leg of the Malthusian model is that overpopulation presses income down through diminishing returns. The responses to population growth have always been a subject of debate; scholars have argued that population growth basically triggered technological responses that adapted to the labor/land ratio through the intensification of agriculture (Boserup, 1965, 1981) or even that population growth led to a high rate of technological progress simply because the likelihood of a technological genius appearing in a larger population is higher (Simon, 2000; Kremer, 1993). Yet the main argument for diminishing returns that has been relied upon by Malthusians or neo-Malthusians is the finiteness of non-reproducible resources. As land and natural resources have declined in their share in national income, the assumption that there is a permanently "fixed" factor in the economy that limits the growth of per capita income is weakened by the enormous growth of land- and resource augmenting technological progress that has occurred in the past century.[4]

Rent-seeking and Predation

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[3]The evidence for the existence of Malthusian checks in which disasters occur as a result of overpopulation is scant. Nineteenth century writers believed that the Irish Famine was a clear-cut example, but the evidence for overpopulation as a clear cause of the Famine is far from persuasive (Mokyr, 1985).

[4]The most striking land-augmenting inventions were fertilizers and pesticides, of which by all accounts the most dramatic was the Haber-Bosch nitrogen-fixing process, which according to Vaclav Smil accounted by the end of the twentieth century for at least 2.4 billion being alive because the proteins in their bodies could be synthesized from amino acids whose nitrogen originated in this invention (Smil, 2001, p. 204).

Perhaps the least noticed reason why incomes before the Industrial Revolution were more or less stationary and stagnant is that most economies were "extractive" in the nomenclature popularized by Acemoglu and Robinson (2012) and found themselves in a "natural state" (North, Wallis and Weingast, 2009). In these states, dominant elites extracted rents from the rest of the population. The institutional weakness of these societies was not so much that there was "rule of law" as much as that it was a rule of bad law, a legal system that was biased toward the politically powerful and favored a rapacious rent-seeking minority. The absence of any concept of "equality before the law" in most societies meant that economic success always risked the attention of greedy strongmen, above all of course the rulers, whose ability to expropriate the wealth of successful individuals remained a constraint on the incentives of would-be entrepreneurs.

A notorious example was the French merchant and entrepreneur Jacques Coeur (1395-1456), an immensely rich and powerful merchant who basically monopolized France's Mediterranean trade and was wealthy enough to bankroll many of Charles VII's triumphs in the final stages of the Hundred Years wars against England. His wealth and power attracted the greed and envy of many, and eventually the King joined them. He was arrested and tried on charges that have been deemed trumped-up by historians; the result was that his possessions were confiscated and distributed between the King and his cronies. Three centuries later, a similar fate befell Nicolas Fouquet (1615-1680), the fabulously wealthy tax collector who had enriched himself during the ministry of Mazarin during Louis XIV's minority. He was arrested in 1661 by Louis XIV and imprisoned for the rest of his life; his sumptuous chateau was stripped by the King's servants. Only in areas in which the political influence of successful merchants, industrialists, and financiers could protect them from such expropriations did entrepreneurs feel comparatively safe from the threat of expropriation or confiscatory fiscal extraction. There were many such places in Europe, to be sure, but rent-seeking remained pervasive in the age of mercantilism and clearly presented an obstacle to economic growth (Ekelund and Tollison, 1997) even when property rights became more secure.

The existence of such legal protections was insufficient, however. Many of Europe's most successful pre-Industrial Revolution economies were located in relatively small political entities, some of which were classic city states. The enrichment of such entities is explained by their ability to set up city governments that were protective of merchants' property (Gelderblom, 2013). Many urban areas were able to raise living standards above the subsistence levels that Malthusian fundamentalists believe constrained living standards. In the highly fragmented and violent Europe before the Enlightenment, however, such wealth attracted strong but poor foreign predators as honey attracts flies. The wealthy towns of northern Italy were ravaged in the early sixteenth century by Spanish and French soldiers (not to mention condottieri from a variety of origins) and most of them did not recover. German trading towns such as Augsburg, Magdeburg, Frankfurt-on-Oder, Stralsund, and Prague among many others were mercilessly looted and sacked by the mercenary armies that roamed Germany during the thirty-years war. Since none of those armies could provide its supplies, they had to impose enormous extortions on the territories it moved through.[5] As a recent essay points out, it was not only much war itself as the actions of the military that had devastating effects on the countryside. Soldiers looted all around them, and they caused a great deal of risk that discouraged farmers from cropping land and raising animals too exposed to danger. They note that in France this was especially disastrous during the wars of religion (1572-98) and the wars of the Fronde (1648–

[5]These extortions, known as *Kontributions* or *Brandschatzung* were a combination of confiscatory taxation and extortion imposed on local towns and countryside and armies often chose itineraries that led through the most prosperous areas. See for instance Guthrie, 2003, pp. 30-31.

52) (Béaur and Chevet, 2017, p. 85). The deadweight losses of such actions were thus enormous. Other cities that were spared had to invest heavily in fortifications, such as Hamburg or paid off the soldiers to prevent looting.

The most striking example of what could best be called negative institutional feedback is provided by the Low Countries, a region of Europe that repeatedly broke through the Malthusian barrier to provide its citizens with a standard of living considerably higher than the subsistence level implied by the iron law. Yet powerful neighbors threatened their prosperity: France and Spain repeatedly, but after 1648 England just as much. The wealthy medieval towns of Ghent, Bruges and Courtray had to repeatedly fend off French invaders in the Middle Ages; the Burgundian rulers of the fifteenth century allowed them to return to prosperity, which was rivaled by the meteoric rise of Antwerp in the sixteenth. But after 1555 these provinces were part of Spain, and Spain was a violent and predatory master. By 1585 (the notorious sack of Antwerp), much of Flanders and Brabant's prosperity had declined. The Southern Netherlands entered two centuries of sustained stagnation. In their place of course came the Northern Netherlands, which was more favorably located (as they could fend off invading armies by flooding the lands). Yet it, too, had to spend inordinate amounts on defense, which by the eighteenth century were a contributing factor in the economic stagnation of the United Provinces. Britain's success in the Industrial Revolution was at least in part due to the fact that no hostile ruler after William the Conqueror had successfully invaded it or could even threaten so credibly.

Part of the reason why growth was so vulnerable in the pre-Industrial Revolution era is that most growth was "Smithian" in nature, that is, it was fueled by gains from trade and specialization. Such growth tended to be vulnerable to political shocks, including the use of state-sponsored pirates (known as privateers) and economic embargoes of various kinds. Mercantilist protectionist policies, whose primary purpose was political rather than economic, played an important role in diverting and distorting trade flows, and even ended up distorting consumption patterns in the long run (Nye, 2007).

In short, through much of history, a combination of internal rent-seekers and predatory foreigners were attracted to places in which economic success had allowed the local population to accumulate wealth. In so doing, they were of course killing the goose the aid the golden egg, but especially during war time, when the future was discounted heavily, such expropriation was often resorted to. A high rate of discount — as would occur during war — could turn a stationary bandit into a roving one. As a result, even when economic growth occurred, it was often undone by its own success in a dialectic way.

This negative feedback has largely disappeared in modern economies. Between 1750 and 1850 much of mercantilist rent-seeking disappeared in Britain (Mokyr, 2009, pp. 423-427). In most developed western democracies, rent-seeking is at at low levels. To be sure, rent-seeking has far from disappeared world wide in our time. In some countries it has degenerated into modern kleptocracies, in which massive theft and corruption by ruling elites have condemned large economies to economic stagnation or worse: Venezuela, Nigeria, and Russia are prominent examples of such rent-seeking-run-amok. Yet on the whole in many of the most successful countries rent-seeking has been kept within limits and corruption in these countries does not reach the dimensions at which it seriously threatens entrepreneurship and economic progress. In those countries governance is of a relatively high quality and political risk does not seriously jeopardize the actions of successful entrepreneurs and companies. It is not surprising that in many of the most advanced and successful countries the corruption indices compiled by Transparency International and the World Bank are quite low. Not all rent-seeking takes the form of corruption, of course, and no simple index of rent-seeking exists. Yet in most low-corruption countries, the kind of blatant rent-seeking embodied in the six WB "governance indicators" are in the top percentiles.[6] These indices are quite strongly correlated and conceptually one could think of some principal component that would combine the six into some "quality of institutions" variable.[7] It is fair to state that the quality of these institutions in some of the most economically successful economies such as Denmark, Canada, and Singapore is higher than it has ever been in history. At the same time, the threat of economic nationalism and notions of "fair" trade (a euphemism for protectionism) seems an indestructible weed in the garden of trade.

Technology and Knowledge

Some technological progress was a feature of many economies, including many in which growth was so slow that we would surely call them suffering from secular stagnation. Invention did occur, and in some cases invention was of a game-changing nature (think of the mechanical clock and the moveable-font printing press invented in the late middle ages). The medieval economy, far from being technologically backward or even stagnant, was actually quite dynamic on a host of fronts in agriculture, manufacturing, civil engineering, shipbuilding, and metallurgy. Yet the impact

[6] They are: Voice and Accountability; Political Stability and Absence of Violence; Government Effectiveness; Regulatory Quality; Rule of Law; and Control of Corruption. See http://info.worldbank.org/governance/wgi/index.aspx#home.

[7] The pairwise correlation coefficients of three of the measures that are closest to rent seeking are especially high: between "control of corruption" and "government effectiveness": R = .909; between "control of corruption" and "rule of law" R = .962; and between "government effectiveness" and "rule of law" R = .940.

of these breakthroughs on economic well-being usually was quite small and temporary; none of them were translated into anything that looked remotely like economic growth. One may wonder why.

The effectiveness of sustained technological progress depends to a great extent on the *epistemic base* of the invention, namely how much is understood by the inventor and users of why and how the new technique works (Mokyr, 2002, pp. 31-32). Technological progress occurred through much of history, but there was something deeply different in the innovations during and after the Industrial Revolution. Before 1750, the vast bulk of inventions had occurred through serendipity, experience, continuous trial and error, and the gradual accumulation of small incremental improvements. The techniques worked, but nobody quite understood how and why they did so. Blacksmiths made steel, brewers brewed beer, and farmers fertilized their fields, but nobody had much of an idea of the chemical and biological processes at work. The nature of combustion, one of the most elementary techniques used throughout manufacturing, was not understood until the late eighteenth century. Even during the Industrial Revolution itself, some of the great breakthroughs — especially those in the mechanical parts of the cotton industry — were the result of mechanical intuition and tinkering rather than any profound understanding of the underlying physics or biology. It was possible to discover new products and techniques that work better when their underlying natural rules are not known, but it makes it much harder to debug, improve, and adapt a technique, and it is those improvements that most of the productivity gains can be founds. Hence most inventions were one-off events followed by slow, artisan-driven improvements that eventually eventually petered out. At times such incremental improvements could actually account for substantial productivity gains over time, as was the case in the British watch industry in the eighteenth century (Kelly and Ó Gráda 2017). In other cases, a minimum epistemic base was required before a technological advance can be made that affects the economy, as was the case with electricity or nitrogen-fixing.

The problem with premodern technology, then, is quite simply that even the smartest natural philosophers did not know enough to give farmers, brewers, shipbuilders, blacksmiths, physicians, and all other *fabricants* much sound advice on why their techniques worked, and hence they could not tell them how to make them work better, not could they suggest to would-be inventors what would work and what would not. As a result, even when a technique clearly worked, it was often used inappropriately. The great transition of the Industrial Revolution was not the growth of invention as such but its changing nature. What made it "modern" is the gradual widening epistemic base of technology.[8] Some of it came from the autonomous growth of science, often inspired by practical problems. After many centuries of experience-based steel-making, in 1786 three French followers of Lavoisier wrote a pioneering paper proposing the chemical composition of steel (though it took decades for it to be actually of use to steelmakers).[9] Water power had been known since antiquity yet advanced painstaking slowly, through trial and error until about 1700. Its accelerated

[8]Justin Lin (1995) points out that the difference between Chinese and modern Western technology was that both Chinese and pre-1700 western technological progress were experience based, and advanced through learning-by-doing and trial and error. The growth of what he calls knowledge-based technological change changed the historical balance in favor of the West. This was already realized in the eighteenth century. Condorcet in his famous 1795 essay on human progress argued that although "isolated nations long influenced by despotism and superstition" (he means in all likelihood Asia) had been the origin of many important new technologies in textiles, ceramics, and metal, it was being surpassed by Europe in his age because there is nothing these that "announces the presence of genius — all improvements there appear as the slow and painstaking work of a long routine" (Condorcet, 1796, p. 51).

[9]The famous paper was by Claude Berthollet, Gaspard Monge, and Alexander Vandermonde, "Mémoire sur la fer consideré dans ses differens états métalliques," published in France in 1786. It explained the scientific nature of steel, but its quaint terminology may have made it "incomprehensible except to those who already knew how to make steel" (Harris, 1998, p. 220). But five years later the British chemist and physician Thomas Beddoes published a paper that relied on it and by 1820 it was well known enough to be made into an article in the *Repertory of Arts, Manufactures and Agriculture* (Boussingault, 1821, p. 369), which noted that idea had been adopted by all chemists who had turned their attention to the subject. For details, see for instance Wertime, 1961, pp. 188-89.

improvement was due to a combination of better experimental techniques and the systematic use of formal science in its analysis (Reynolds, 1983, pp. 204-65; Wootton,2015, pp. 486–89). Gaslighting, one of the paradigmatic inventions of the Industrial Revolution, was supported by the development of the concepts, materials, experience and apparatus of pneumatic chemistry (Tomory, 2012, pp. 13-36). The same was true for fertilizer: farmers had been fertilizing fields for millennia, but nobody knew why and how fertilizers made crops grow more abundant. Once that became known through the emergence of organic chemistry in German in the 1830s and 1840s, farmers could apply chemical manures as needed for specific crops.[10]

By no means does this suggest that the understanding of a technique was fully developed when it was first developed — but in many cases some minimum had to be in place. Once operational, however, the invention stimulated scientists to develop the underlying science and widen the epistemic base endogenously to allow for further improvements. The classic example remains the steam engine, which required an understanding of atmospheric pressure before the notion of building one could occur to anyone. Once this was made (by Torricelli in 1643), the atmospheric engine could follow. Yet the science of steam engines was not fully understood until a century and a half later and the old gag that science owed more to the steam engine than the other way around remains one of those oft-repeated half truths that confuse as much as they enlighten. *Some* formal science mattered. Even though the physics of steam power (that is, thermodynamics) was almost a century away, James Watt had learned from the Scottish chemist William Cullen finding that in a

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[10] Another example is hydrostatics needed for ship design, with which eighteenth-century scientists struggled mightily. Newton's theory on this known later as impact theory was embraced by many contemporaries, but turned out to be unsatisfactory and was corrected by the Bernoullis and Leonard Euler who designed a theory that could deal with the physical state variables in the whole domain of the fluid. See Nowacki (2008).

vacuum water would boil at much lower, even tepid, temperatures, releasing steam that would ruin the vacuum in a cylinder. That piece of knowledge was essential to Watt's realization that he needed a separate condenser (Hills, 1989, p. 53).[11]

When did the stronger connection between propositional knowledge (knowledge of "what") and prescriptive knowledge (knowledge of "how") begin? It clearly did not erupt suddenly in 1500 and medieval natural philosophers and inventors were, as already noted, far from the benighted ignoramuses that subsequent writers have tried to make them seem (Hannam, 2011). Yet the notion that useful knowledge was primarily meant, as Bacon famously wrote, to be "a rich storehouse for the glory of the creator and the relief of man's estate" only fully took hold in the sixteenth and seventeenth centuries, when scientists repeatedly pointed to artisanal knowledge as a source of inspiration. Many decades ago, Edgar Zilsel (1942) pointed to artisans and craftsmen as a major source of information for philosophers, and the explicit acknowledgment of their role by many of the leading scientists of the age.[12] In the two centuries before 1700, the social distance between "pure" natural philosophy and its application slowly but irresistibly shrunk in western Europe. To be sure, much of natural philosophy remained cloaked in mysticism and occult, but by the late seventeenth century more and more scientists emerged following the model of John T. Desaguliers in England and Antoine Parent in France, who applied their knowledge of physics and mathematics to the solution of practical problems in mining and watermills.

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[11] A paradigmatic example of how practical invention stimulated the underlying science rather than the reverse can be found in the evolution of aerodynamics. The formal theory of aerodynamics was laid out in 1918 by Ludwig Prandtl, fifteen years after Kitty Hawk (Constant, 1980, p. 105; Vincenti, 1990, pp. 120–25). Even then, the ancient method of trial and error was still widely used in airplane design. The search for the best use of flush riveting in holding together the body of the plane, or the best way to design landing gear remained highly experimental (Vincenti, 1990, pp. 170–99; Vincenti, 2000).

[12] For a more recent restatement of Zilsel's ideas, see for instance Roberts and Shaffer (2007).

The reason that the Great Enrichment could sustain itself, then, is that between 1700 and 1850 the epistemic base of many areas in technology widened continuously, in part through cumulative progress in science and in part a response to challenges and stimuli coming from the practical world. In the nineteenth century we see an ever-increasing input of formal knowledge in the origins and — even more so — in the subsequent development of new techniques.

Where a social and informational chasm separated those who knew things and those who made things, the mutual reinforcement of artisanal and formal knowledge was much harder to bring about and a stationary state of little or no growth would ensue. Scholars in the Greek ancient world were still committed to *banausas*, a sense of contempt for practical knowledge, a contempt that the Romans shed to a great extent, at least for a while, as exemplified by the practical work of writers such as Cato the Elder, Vitruvius, and Varro. In this (late Republican) period, Macmullen (2017, p. 15) notes, "Mediterranean civilization could be thus raised to new levels of tangible comfort, health, and handsomeness upon the basis of knowledge necessarily shared between the ruling classes and labor, with master craftsmen to bridge the gap between the two." Unfortunately, this cultural trait did not last, and Rome did not generate a sustainable process of technological progress. In China, similarly, the gap was becoming more formidable in Ming and Qing. Needham has pointed, for example, to the fact that the real work in Chinese engineering was "always done by illiterate or semi-literate artisans and master craftsmen who could never rise across that sharp gap which separated them from the 'white collar literati'" (Needham, 1969, p. 27). One of the characteristics of Enlightenment Europe was that in many areas this chasm closed considerably. There was a widely shared conviction that artisans and scientists could benefit from another and in much of western

Europe places and forums at which natural philosophers and mathematicians could interact with engineers and industrialists came into being (Stewart, 1992; Mokyr, 2009).

Secular Stagnation?

If it is accepted that the three factors listed above accounted for a substantial part of secular stagnation in the past, they provide us with a way to reassess the likelihood of secular stagnation as a normal condition in the foreseeable future. As far as the specter of a Malthusian curse is concerned, the notion that the human race is facing some risk of overpopulation (still popularized by Paul Ehrlich's *Population Bomb,* first published in 1968, followed unrepentantly in 1990 by his *Population Explosion*) has been thoroughly discredited. Even without the huge increase in effective and available natural resources due to technological progress, this doomster prediction is doomed itself by the astonishing slowdown in fertility rates world-wide. Fertility rates in developing economies in Asia and Latin America are mostly hovering around replacement. The most populated economies in Asia are experiencing declining fertility that are approaching or have fallen below replacement fertility. Indonesia and Bangladesh, for instance, today have fertility rates of 2.13 and 2.19, down from 5.7 and 6.7 in 1960 respectively (CIA handbook and World Bank, respectively), while China and Iran are now both significantly below replacement levels. The main area of concern, where Malthusian pressures may remain a serious limitation to growth, is Africa. African fertility rates have remained stubbornly high and the resource base in most of the Continent is being eroded by over-use and mismanagement. For the rest of the world, the demographic transition, whatever its exact microeconomic foundations, is steering toward zero population growth now predicted for some point in the twenty-first century.

Indeed, it is no small irony that if demography is any concern today, it is that zero or negative population growth, coupled with the continuing rise in the average age in most economies, is seen as a source of secular stagnation (Hansen, 1939). Globally, the old-age dependency ratio is expected to rise from 13 percent in 2015 to 38 percent by the end of the twenty-first century (*The Economist*, 2017, p. 3). But the notion that somehow an aging population will lead to declining aggregate demand seems unpersuasive. For one thing, assuming retirement rates do not change much, a rising dependency rate means that aggregate demand will exceed aggregate supply, as rising numbers of non-working persons will still consume. Second, the notion that somehow slow or zero population growth slows down investment seems weak: it seems more likely that it will change the composition of investment, toward medical care, tourism, and more home services for the elderly. New technologies can and will substitute capital for labor in a range of such activities. Moreover, the inevitable crushing expenses of medical care and pensions will mean that government spending will have to increase, offsetting any shortfall of aggregate demand. The negative effects of aging on GDP growth will be particularly felt if most of the population over 65 will leave the labor force.

Moreover, there is nothing sacrosanct about the 65 years cutoff which is a relic of the nineteenth century. Increased labor force participation of the "pre-tired" age brackets 65-80 holds one of the keys to future growth just as increased female participation did in the 1960s and 1970s. Modern medical technology has extended the number of years the post-65 cohort can remain productive and future technological progress suggests that this will continue to improve.[13] The more

[13]There is research that suggests that in repetitive work, productivity declines with age, but that in knowledge-based jobs age makes no difference in performance and that in those remaining "social skills" productivity rises with age (*The Economist*, 2017, p. 6). As automation and the increase use of artificial intelligence will replace repetitive work, but not the kind of work that requires knowledge or social skills, this suggests that the labor market bias against workers over 50 may be doomed. This may be augmented by the ability of elderly workers to increasingly participate in the "gig economy" by for instance driving Uber cars, letting rooms through Airbnb, or providing babysitting services through

those in the 65-80 bracket can be deployed productively, the more such concerns will be mitigated. More than anything else, however, the concern is with declining *GNP growth*, which — because it ignore changes in leisure — will fail to capture the huge gain in economic welfare accruing to people who do not wish to work beyond retirement, whose "golden years" are improved by vastly better access to entertainment, better medical technology, greater independence, and (hopefully) some measure of economic security if inflation can be kept under control and old-age insurance markets will adapt.

If there is any substance to Malthusian-driven stagnation for our near future, it might be that the finite resource is not "land" or even natural resources, but the overall limited capability of the planet to carry a *richer* population rather than a *bigger* one. Even if population growth is no longer a factor, it may be argued that rising income per capita on a global scale is self-limiting because it exhausts the finite resources that the world can produce— which include maintaining a stationary temperature distribution. While resistance to economic growth in any form may be a tenet of some extreme environmentalist groups, it is not based on any economic principle and will remain a fringe opinion. After all, growth can be natural-resource using (as it was in the first centuries of the Industrial Revolution when fossil fuel and iron consumption increased by a huge factor), but it can also be resource saving, if growth takes the form of renewable energy investment, public transportation, the recycling of materials, and such. In other words, resource considerations may still be a steering mechanism of the growth vehicle, but are unlikely to become the brake. Whether or not such resource augmenting technological progress will actually happen remains to be seen; in terms

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such sites as sitters.com. Technology also allows the elderly to cope with many of the handicaps of old age, including on-demand services and smart appliances. As the generation that is comfortable with smart phones and computers now comes into their sixties and seventies, this will become easier to implement.

of both demography and technological change, we live in times that have no parallel in the past, and so History may be a poor guide to the future.

Politics and growth-hostile institutional change are more of a concern. It should be obvious that in the present world order, a war of predation against small but wealthy nations is rather unlikely even if they have powerful but poor neighbors. Singapore is at first glance uncomfortably hemmed in between two larger and poorer neighbors, Indonesia and Malaysia. Its income per capita exceeds that of Malaysia by a factor of 3.2 and that of Indonesia by a factor of 7.4, yet its population is tiny compared to either. All the same, the likelihood of a predatory war against it is very low. Indeed, the last time that such a predatory war can be seen to have taken place was Saadam Hussein's invasion of Kuwait in August 1990, which ended disastrously for him. The international order, through formal multinational institutions such as NATO and the UN as well as informal institutions such as US-led coalitions will not tolerate such predatory attacks, and potential predators know this full-well. Rather than full-scale roving-bandit raids, however, there is a danger that medium-sized but poor nations could engage in the future in nuclear blackmail.

The issue of *internal* rent-seeking is far more complex, and here, as already noted, stagnation driven by paralyzing levels of corruption and ineffective governance can indeed threaten the future of growth in many countries. One of the hardest questions to predict is whether modern countries that have been able to confine cronyism, nepotism, and rent-seeking to tolerable levels will become more corrupt over time, or whether corrupt countries will slowly engage in institutional reform and eventually reduce corruption to manageable levels. When highly corrupt nations interact closely with nations with better institutions, or join supranational organizations with them, one would hope that some reforms would take place. Romania and Bulgaria joined the EU in 2007; since then most of the World Bank worldwide governance indicators have improved somewhat for Romania but less so for Bulgaria.[14] For Greece, which joined in 1981, the data do not go back all the way to the time of joining, but the trend of the governance indicators for it since 1996 are quite discouraging. In China, the campaign against corruption seems to have led to major improvements in the three most crucial indices in the past decade: in "control of corruption" China moved from the 31st percentile to the 50th, and in "government effectiveness" from the 53rd to the 68th. Greater integration in the world economy may thus have had salutary effects on institutional quality — yet this has not turned China into a more democratic and open polity. The "voice and accountability" variable remains very low and had declined between 2005 and 2015 from 7.6 to 4.9.

Whether and how the rise of authoritarian regimes in the twenty-first century will actually affect governance quality is far from clear. In some cases a highly authoritarian regime can turn countries away from corruption if the autocrat — one thinks above all of Lee Kuan Yew — has him or herself high ethical standards. There is no easy way to predict whether the new autocratic regimes established in some countries will be more like Lee or more like the egregiously corrupt and erratic

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Romania		2007 (percentile rank)	2015 (percentile rank)
	Government effectiveness	45.15	51.92
	Rule of Law	52.15	61.06
	Control of Corruption	53.88	57.69
Bulgaria			
	Government effectiveness	53.40	62.02
	Rule of Law	51.67	52.88
	Control of Corruption	51.46	48.56

Source: World Bank Governance Indicators, http://info.worldbank.org/governance/wgi/index.aspx#reports

Nicolae Ceauşescu. Clearly location is correlated with the kind of cultural foundations that help determine the quality of governance. The three Baltic nations, all formerly soviet republics, have European-level scores on their governance indicators, while the Central Asian Republics score abysmally on almost all indicators.[15]

Yet history suggests some room for optimism. It is possible for countries to change their political structure fairly quickly if there is a profound cultural-ideological change such as the European Enlightenment of the eighteenth century. "Old corruption" declined in Britain after 1750, under the leadership of William Pitt the Younger and Edward Burke (Mokyr, 2009, pp. 424-427) . By 1850, Britain was a nation in which rent-seeking had been reduced to a minimum. The same was happening in Prussia, the Low Countries, Scandinavia, and Switzerland. There can be little question that the countries affected most by the Enlightenment and its spread after the French Revolution (and their overseas offshoots) are still the ones that tend to score the best on the World Bank and Transparency International corruption indices in our time.

The one concern that may arise is that bad institutions will support resistance to innovation, as incumbents will try to block innovations using a variety of political and rhetorical devices, from concerns about employment opportunities being eroded because of automation to imaginary fears about "frankenfoods". Such fears are a real concern (Mokyr, 1998, 2008 ; Juma, 2016). A good case in point is transgenic crops. As Juma (2016) notes, the use of such crops is not only a way to increase agricultural productivity but also environmentally responsible, as it leads to lower use of pesticides and fertilizer. Yet it is opposed by a coalition that led to the formulation of the infamous Cartagena

[15] At the same time, idiosyncratic and contingent factors can override both geography and history. Consider the sharp contrast between neighboring Poland and Belarus: In 2010, Belarus scored in the 27.14 and 15.17 percentile on "control of corruption" and "rule of law" while Poland scored 70.00 and 68.25 respectively. By 2015, the gap between the two countries had declined somewhat.

protocols of 2000. The main thrust of this emblematic manifestation of resistance to transgenic crops, known as the "precautionary principle," was to reverse the burden of proof: the originator of the biological innovation had to show it was harmless before it could be marketed — basically an impossible task. As Juma stresses, the logical error of those driven by loss- or risk-aversion is to assume that the status quo is risk-free. Yet it remains to be seen if such resistance will be more effective now than it has been in the past. International competition will make resistance costly, since nations that adopt the best techniques clearly will out-compete others.

All in all, it is unlikely that in our own age long-term economic growth world-wide would be stifled by bad governance and rent-seeking. This is not to say that there are no countries or even large segments of continents in which economic growth is impeded and even stifled by endemic corruption and poor institutions. Global competition between nations has at times induced nations to engage in institutional reform, but these reforms seem especially prevalent after violent conflict such as the Stein-Hardenberg reforms in Prussia after 1806, the abolition of serfdom in Russia after the Crimean War, or the re-introduction of liberal democracy in Italy and Germany after 1945. The problem, as always, is that the decision makers in high-corruption nations are normally people who benefit from rent-seeking and whose power depends on it; they are unlikely to voluntarily support reforms unless they feel they have to. Yet the overthrow of such venal dictators as Ceauceşcu, Yanukovych, and Mubarak shows that such things are possible even if corrupt regimes are not invariably replaced by a better one.

Finally, the question of whether in recent times our knowledge of nature provides us with a better way of developing and improving technologies seems relatively easy to resolve. Modern science has penetrated to the atomic and subatomic level as well as to remote outer space with ever more powerful tools. That is not to say that we fully "understand" why and how nature operates or that we ever will, only that we have a better grip on regularities and patterns that can be exploited and harnessed to our needs. The basic reason is quite simple: we have far better tools and techniques to observe natural phenomena and patterns than in the past, and those who need to know have far better access to the rapidly expanding body of useful knowledge.

To put it differently, against the concern that in the past century the "low-hanging fruits have been picked" and that innovation is getting increasingly difficult, it can be argued that science provides us with taller and taller ladders. But that is not the entire story. Technology and science co-evolve in a powerful positive feedback relationship. Science advances when it has better tools. Seventeenth century science in Europe blossomed in large part because it produced new instruments, most famously the telescope, the microscope, and the vacuum pump. In the twentieth century, one of the unsung heroes is x-ray crystallography, first proposed by the German theoretical physicist Max von Laue (1879-1960) and realized by William Henry Bragg (1862-1942). The technique has been instrumental in discovering the structure and function of many biological molecules, including vitamins, drugs, and proteins. Its most famous application was no doubt Rosalind's Franklin's work in 1953, which led to the discovery of the structure of the DNA molecule, but its use has been instrumental in twenty-nine other Nobel-prize winning projects (International Union of Crystallography, 2017).

In the past fifty years the toolkit that scientists and researchers in any area have at their disposal have improved and expanded at an undreamed-of rate. Old tools like microscopes and telescopes have been improved beyond any imagination, to the point where the developers of the Betzig Hell super-resolved fluorescent microscope were awarded the Nobel prize for chemistry. The telescope, similarly, underwent such radical improvements that the James Webb Space Telescope, to be launched in 2018 will be able to study the origins of galaxies and search for planetary systems in the universe in ways unimaginable before. Every laboratory in the world today uses equipment that is vastly superior to what was available in the late twentieth century. Research in any imaginable area was enriched in the past half century by two "general-purpose scientific instruments," computers and lasers. The impact of computers on science has gone much beyond simple calculations and statistical analysis: a new era of data-science has arrived, in which models are replaced by colossal mega-data-crunching machines, that detect patterns that human minds could not have dreamed up and cannot fathom. Such deep learning models engage in data-mining in artificial neural networks. Rather than dealing with models, such regularities and correlations are detected by powerful computers even if they are "so twisty that the human brain can neither recall nor predict them" (Weinberger, 2017, p. 12). Here the slogan might well be: who needs causation as long as we have correlation? In some sense, there is nothing new here: there was always an inductive method in science, in which scientists collected data on plants, shells, and rocks and looked for regularities without a full understanding the underlying laws. The difference is just in scale, but in these matters scale is everything. Much as the much-touted James Webb is to Galileo's first telescope, the huge data banks of mega crunchers are to Carl Linnaeus's notebooks.

But computers can do more than crunch data: they also simulate, and by doing so, they can solve fiendishly complex equations and allow scientists to study physiological processes and design new materials *in silico* and simulate natural processes that hitherto defied human attempts. Such simulations have spawned entirely new "computational" fields of research, in which simulation and large data processing are strongly complementary in areas of high complexity.

Much like computers, lasers have been used very widely in industry and medicine, but their power as a scientific tool may be just as significant in the long run. Much more than computers, the laser surprised its original inventors with its many uses in scientific research. Among its many applications, one of the most important is LIBS (Laser Induced Breakdown Spectroscopy), which is an astonishingly versatile tool. It is used in a wide range of fields that require a quick chemical analysis at the atomic level, without sample preparation. LIBS is applied in remote material assessment in nuclear power stations; geological analysis in space exploration; diagnostics of archaeological objects; metal diffusion in solar cells; in biomedical applications to analyze biological samples like bones, tissues and fluids, and to detect excess or deficiency of minerals and toxic elements in bodies. LIDAR (light radar) is a related surveying laser-based technique which creates highly detailed three-dimensional images used in geology, seismology, remote sensing, and atmospheric physics. But lasers are also a mechanical tool that can ablate (remove) materials for analysis. For laser ablation, any type of solid sample can be ablated for analysis; there are no sample-size requirements and no sample preparation procedures. Chemical analysis using laser ablation requires a smaller amount of sample material and a focused laser beam permits spatial characterization of heterogeneity in solid samples. Among its many other uses, laser interferometers have been used to detect the gravitational waves Einstein postulated, one of the holiest grails in modern physics.

In addition to better tools of actually conducting new research, the modern age has revolutionized *access* to the existing pool of scientific knowledge. As the body of scientific knowledge is increasing continuously, the question of *access* looms ever larger. The reason access is important is well-understood. Inventors need to have access to best-practice science on the frontier to push the envelope and make sure they take technology as far as can possibly be taken conditional on the largest epistemic base. Moreover, they need to know what already exists so as to avoid re-inventing an expensive wheel. Finally, many inventions consist of recombinations of existing devices, in which disparate elements are put together in new ways, in Ridley's famous formulation, "ideas having sex." Hence, the people working at the frontier need to know what is already known by others. The only way to define "that what is known" (social knowledge) is as the union of all scientific knowledge known to individuals. Yet because, access is crucial.

As scientific knowledge has expanded since 1500, an inevitable process of specialization has taken place. Scientists know more and more about less, and there are fewer and fewer "polymaths."[16] The "burden of knowledge" is increasing, and the amount that scientists working at the frontier have to learn is growing (Jones, 2009). Often the relevant knowledge is quite remote from one own's specialization and requires access, and access requires an access technology. It is no accident that the age of Enlightenment, during which the Industrial Revolution shifted into high gear, was also the age of the encyclopedia which organized existing knowledge and made it accessible. Many "handbooks" and "technical compendia" were compiled by groups of experts, and they were disseminated through cheap print editions and local libraries with the explicit purpose of making useful knowledge accessible.[17]

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[16]Indeed, there are two separate books entitled "The Last Man who Knew Everything." One of them (Findlen, 2004) places the title on the Jesuit scholar Athanasius Kircher (1601-1680), a German-born polymath of prodigious scholarly productivity who wrote important books on topics as different as natural history, mathematics, geology, and the history of ancient Egypt. The other is Thomas Young (1773-1829), a physician who established the wave theory of light, discovered a formula for the elasticity of materials, and helped decipher Rosetta's Stone (Robinson, 2007).

[17]A good example is Thomas Croker's three-volume *Complete Dictionary* (1764–66) which explicitly promised its readers that in it "the whole circle of human learning is explained and the difficulties in the acquisition of every Art, whether liberal or mechanical, are removed in the most easy and familiar manner." In close to 2,000 pages, the collection contained detailed essays on a diverse array of topics such as Architecture, Botany, and Hydrostatics.

The race between storage-and-search techniques and the growth of scientific content in the last few years seems so far to have been won by the former. Anyone engaged in research can access vast banks of knowledge and data. Cloud technology is just getting started. We measure storage now not in petabytes but zettabytes (a million petabytes), yottabytes (a thousand Zettabytes) and brontobytes (a thousand yottabytes). Moreover, search and storage costs have fallen faster in the past decades than ever before.[18] As Matt Ridley (2010) has remarked, "The cross-fertilization of ideas between, say, Asia and Europe, that once took years, decades, or centuries, can now happen in minutes." Needless to say, a large part of the information stored is not in any way scientific, and that even much of the scientific information includes more chaff than wheat and requires verification and validation. While access may become easier, validation may become increasingly more costly as the volume of data keeps expanding. That said, the internet and the easy and cheap access to scientific literature and data are now a part of our academic infrastructure. What this means that any process of economic growth based on further expanding the epistemic base of technology will continue apace at least at the rate that we have experienced in the past decades.

The nature of scientific research is changing: Jones (2009) points out that the "burden of knowledge" effects he observes make innovation is becoming more difficult, requires more collaborators, and training people at the point they can make important contributions takes more time, so that "ever increasing effort may be needed to sustain long-run growth" (p. 310). Yet Jones also notes that if improved methods of knowledge transmission occur, then the negative effects of the growing burden of knowledge may be mitigated. The emergence of virtual reality as an

[18] According to one estimate (Goldman, 2013) in 1981 a Macintosh storage drive cost approximately $700,000 per gigabyte. In July of 2013, a Western Digital MyBook cost $0.06 per gigabyte. The cost of flash memory, introduced in 2003, was $8,000 per gigabyte, which fell to $0.94 in 2013 and was about $0.40 per gigabyte in 2016.

educational tool may, in fact, do exactly that. He also notes that if sufficiently new technological opportunities emerge, "the output of innovators may become sufficient, despite a rising educational burden, to sustain growth without increasing effort." The rising efficiency of capital in the production of knowledge due to ever more powerful tools will do exactly that. Bloom et al. (2017) in a careful empirical paper, find that productivity in the generation of ideas has been falling across the board in a slew of existing industries.

At first glance, this seems a worrisome finding suggesting that if we are to avoid secular stagnation and maintain a constant rate of productivity growth, we will need to allocate more and more researchers to the R&D sector. Part of the problem, as Bloom et al recognize, is that in individual sectors diminishing returns to research may set in but that this may not be true for the economy as a whole as new product lines are developed all the time. They deal with this by looking at TFP growth in the economy as a whole and noting that it has actually slowed down as the number of researchers has declined. Equating TFP growth based on GDP statistics with ideas growth or technological progress is of course hazardous, as is well-known. Oddly, they do not note that the number of patents, a measure of output of R&D has been increasing economy-wide at a rate much faster than TFP. Whether Bloom et al. will turn out to be correct or not, it is of course the *total* "output of ideas" that matters for future economic performance, not the output per unit of input. As Bloom et al. stress, ideas are nonrivalrous and so as long as we produce more of them (and their quality does not decline), secular stagnation will not become the rule. It may well have been that in the past the resources allocated to R&D were considerably below optimal, and the increase in R&D may have led to a decline in the marginal product of labor in R&D that was socially optimal. It may also be true that what they observe is a race between the growing difficulty of coming up with new ideas and the growing capability of equipment and instruments to create them. Finally, of course, as the economy gets richer and as robotization and AI may replace even skilled workers, it is possible for the economy to keep increasing the proportion of the labor force engaged in the R&D sector and keep the output of new ideas from declining. What is even more tantalizing, of course, is whether new ideas themselves can be created by AI, which at some point in the future may reverse the trends found by Bloom et al.

So far I have discussed the movement of the technological frontier or best-practice techniques. But what about the process of catching-up by technological followers? European history suggests that technological followers may do quite well. Some of the smaller European economies such as the Netherlands, Switzerland, and Ireland have been able to take advantage of inventions made elsewhere and enjoy high standards of living. It is no secret what makes for successful adoption: a high level of sophisticated human capital that can absorb, operate, and exploit the techniques designed by others (and pay the patent royalties if need be), and institutions that make such adoption easy and smooth, including of course law and order, low political risk, low levels of corruption, and open-ness to new ideas. These make all the difference between a Switzerland and an Afghanistan. What is clear however is that if the technological frontier does not keep moving ahead, the long run stationary state will indeed not be able to avoid the secular stagnation that Alvin Hansen feared.

Conclusions

Secular stagnation was a defining feature of most of recorded history, and has turned into sustained growth only in recent centuries. An examination of what brought that change about suggests that the likelihood of reverting to a world of stasis in the foreseeable future is not high. All the same, one could have legitimate concerns about the sustainability of open institutions that are favorable to growth to keep pace with technological capabilities, and that keeping up a high level of innovation will imply ever-improving tools and equipment, which could change the nature of research in ways that we cannot imagine.

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