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Culture, Coal, Colonies, Computation: The Causes and Perpetuators of the Great Divergence

It is a truth universally acknowledged that the world today, for all its apparent lingering poverty and misery, is really quite wealthy—fantastically wealthy by the standards of 1800. As Dierdre McCloskey is at such pains to point out, productivity has increased over the past two centuries, not by 70%, but by factor of 70 (McCloskey 2016, 7). Average daily wages have gone from $3 a day to $100 a day in the most developed economies, like that of the United States, an improvement of a factor of 30. These numbers are hard to make sense of in the abstract, but they represent a massive change in the standard of living of ordinary people. We tend not to notice the magnitude of this change because it happens gradually, year after year. And considering historical incomes in current-day-dollar-equivalents is at best awkward and at worst misleading, missing much of the content of the changes: no matter how much I made, I could not have purchased a portable computer or paid for electric central-heating in England in 1816, and that $3 coffee that would have entirely eaten up the daily wages of any of my ancestors in the United States (or, God forbid, Finland) in that year would not have been available in the same way—expelled under high pressure from an electricity-powered Italian coffee machine in an electrically-lighted storefront rented by a multinational coffee chain right outside the subway station I get off at every morning—without a sufficient market of $100 per day consumers to pay for all those perks. These sorts of wage comparisons leave out the structural shifts those very changes have made possible. Because we use our money to buy smartphones and ready-made clothes and seven dollar sandwiches we may not live like kings, despite our kingly incomes. But we also do not die like them, by the pox or the *pata*. Just how we managed such a transition in 200 years is indeed something to be explained, and accounting for why it occurred first in Western Europe (particularly with roots in Britain) rather than India, China, or Japan, which had economies superficially similar to Europe's in a great many ways, has resulted in the spillage of much historical ink, of which McCloskey's three-volume, eighteen-hundred page magnum opus is only one of the largest and most recent contributions.

The causes of the Great Divergence are difficult to identify. If we could simulate history thousands of times and tweak the parameters just a bit, they might be easy enough to discover. But we have only one cut of history. Making any generalizations from a sample of N=1 is a fool's errand, so we have to do our best at comparing similar situations within the history we have. Given Europe, China, India, and Japan as a rough set of locales, we now have N=4. Better. But this is still not conclusive. The Great Divergence is almost certainly going to be multi-causal, and the boundaries of these causes are difficult to identify. If one accepts one of the "causal factors" as coal, for example, (as many as far back as Jevons, in 1865, have done), does that mean the cause is a natural one? Or is the cause ideas-about-how-to-use-coal? Or is it a-culture-that-furthers-the-production-of-ideas-about-how-to-use-coal? Which is "more" causative, the resource or the ideas? We have no way to control for these variables—to present ample coal to a Western Europe bereft of bourgeois values, or to provide bourgeois values to a Britain bereft of coal—in order to tease apart such distinctions. So there is no easy way to settle such debates. It seems likely that some are not matters of historical fact at all, but matters of philosophy and sociology, to be settled not by ever more careful study of history, but by good models and even better stories. However, the causes of the Great Divergence are a matter of great public importance. By the standards of our ancestors we are doing fantastically well, and indeed the world is on average still getting wealthier at a significant rate (McCloskey 2016, 43). But accelerating technological and social change, deeply indebted to the model produced during the Industrial Revolution (we are "beholden to the approach to technological change that took root 300 years ago in Europe," as Rosenthal and Wong would have it [ix], and are still living its legacy), puts us at something that appears rather like a key moment in history. The developing economies of India and China are beginning to reach the levels of England or the US in the late 1800s, complete with similar levels of pollution (McCloskey 2016, 68). Africa may be beginning its journey up the "hockey stick," with the specter of global climate change lingering in the background (McCloskey 2016, 71). Mechanization potentially threatens vast new swaths of laborers in routine knowledge work professions (Brynjolfsson and McAfee 2014, Ford 2015). And at home, globalization and neoliberalism seem to have left so many behind. If we are to believe the conventional narrative of Donald Trump's electoral success in Rust Belt states—that economically motivated, primarily white, blue collar workers came out in droves to vote for someone who promised to return to them the employment opportunities and attendant dignity that they (rightly or not) imagined their fathers had—then all McCloskey's pithy barbs about how the tide of liberalism *still* lifts all boats seem to have been of little comfort. While it would be risky to take too exceptionalist a stance about our present moment, historical explanations for the Great Divergence should point us to an urgent contemporary question: What must be done now to preserve and extend the prosperity that industrialization has bestowed upon us? Different explanations for divergence provide different answers.

The general structure of this paper is as follows. First, I outline the key claims of the narratives of divergence, separated into several general categories based on what is attributed as their causal factor. Second, I examine what these claims mean for the maintenance of economic growth today. What are the current implications of each explanation? Then, I attempt to evaluate these explanations in the context of the current progress of automation technologies, via a distinct narrative of economic divergence rooted in the distributed computational power of human societies. This computational hypothesis tries to bring multiple causal factors together into a coherent story that leads us to focus even more closely on how contemporary destabilizations play into growth narratives. Finally, I survey some possibilities for how increasingly advanced techniques of automation stand to shape the factors that contribute to growth, if the computational hypothesis holds.

Narratives of Divergence

The stories of divergence can be usefully, if inexactly, classified into four types. The first class is a demographic one: Western Europe, as compared with other global competitors, was more governed by the preventative, than the Malthusian positive check, and was therefore able to accumulate the necessary initial capital to industrialize. One class is essentially ecological, or resource oriented: Europe had certain types and amounts of natural resources available, at a particular time, that made industrialization possible. Another class is institutional: governments, capital markets, or other societal structures were somehow different in Europe, compared to the rest of the world, and this allowed the shift to an industrial economy. And a last major class of explanations is ideational: it was a proliferation of ideas—ideas about invention, or ideas about how to develop a civil society—that provided the impetus for industrialization. Each of these divergence narratives has potential explanatory strengths, though some have fallen out of favor at various periods in scholarship (this is seemingly cyclical though, as the European marriage pattern has experienced a resurgence of interest in the last decade, see e.g. Voigtländer and Voth 2009). They are all worth exploring, at least in brief, as we begin to think about the sources of our modern prosperity.

Demographic explanations focus particularly on family structure and the European marriage pattern. Typified in John Hajnal's 1965 "European Marriage Patterns in Perspective," this argument essentially states that Western Europe, at least by the 18th century, was unique in the world in terms of its average age at marriage, and the percentage of the population who remained unmarried (Hajnal 1965, 101). This theme, as Hajnal himself notes, is not a new one, but draws directly from Malthus's *Essay on the Principle of Population*, the source of the "preventative check of moral restraint" (Hajnal 1965, 130). Hajnal's paper supports Malthus's claim that, indeed, late marriages and lower marriage rates resulted in lower birth rates and lower death rates within the European population, though the statistics for death rates are less clear cut than those for births. Demography alone does not a Great Enrichment make, but the point for Hajnal is that the marriage pattern is deeply linked to economics: as he puts it, "A marriage almost by definition requires the establishment of an economic basis for the life of the couple and their children," and therefore the economic structure and family structure will shape and influence each other (Hajnal 1965, 132). He supposes that one possible economic consequence of late marriages is greater productivity and demand for goods, as potential partners have longer periods of productive adult life during which they are not raising children, and are able to labor full time, develop savings, and acquire goods "other than the food etc. required for immediate survival" (Hajnal 1965, 132). This is one possible demographic source for the Great Enrichment, which Hajnal refers to as the 'take-off' into modern economic growth. The other co-acting force is that a desire for wealth, and a certain standard of living, may well have delayed marriage, such that the delaying of marriage could be self-reinforcing and add strength to the effect. These forces are connected to European family structure and the cultural expectation that young couples establish their own independent household rather than join a larger co-habitating economic unit like an extended family, as was customary in China and elsewhere (Hajnal 1965, 133). But the precise causal relationship here is unclear.

Eric Jones's *The European Miracle*, though it also addresses other factors such the natural environment and European colonization, gives European family structure a central role in making the "miracle" possible. Jones generally aligns with Hajnal in his treatment on the European family, as uniquely characterized by a nuclear structure and capable of controlling fertility preventatively in response to the availability of resources. The rest of the world, as Jones put it, were "*r*-strategists," maximizing their numbers to cope with catastrophe, but where therefore always in danger of running headlong into the Malthusian positive check of resource exhaustion, famine, disease, and death (Jones 1981, 20). Western Europe, the space of carrying-capacity sensitive "*K*-strategists," was meanwhile able to accumulate ever more capital, the fruits of excess production not overtaken by population growth, which set the stage for the Industrial Revolution. Pomeranz details the precise sorts of mechanisms through which this process would purportedly operate: an increase in the number of non-farmers, better tools, more livestock, better nourishment and health leading to greater productivity, and a larger market for non-essential goods (Pomeranz 2000, 10). However, the demographic thesis has been challenged by more recent scholarship which has tended to show that Europe and Asia were less different than Hajnal and Jones believed. Voigtländer and Voth dispute the relevance of "California School" findings about Yangtze productivity to the overall incomes of Europeans and Asians, but evidence overall suggests Asia was no Malthusian disaster (Voigtländer and Voth 2009, 248). Rises in living standards occurred elsewhere too, during various periods, and much of Asia could have accommodated even higher population densities during the 1800s without major changes in either productive technologies or the general standard of living—which was, in some respects, higher than that in Europe (Parthasarathi 2011, 11)—which sheds further doubt on the idea that Asia was, demographically, too close to Malthusian collapse to be able to support industrialization (Pomeranz 2000, 11). Instead, if we are to accept demography as part of the explanation for divergence, it would need to be in terms of a more sophisticated argument of path-dependence and sociopolitical goals, as Parthasarathi attempts to provide, rather than via naïve overpopulation and overstressing of an agrarian economy. Likewise, Sugihara Kaoru suggests that the population growth of Asia represents an "East Asian miracle" of comparative scale and value to the European miracle, in that Asia was capable of supporting complex societies of artistic and technological achievement at population levels not seen in Western Europe (Pomeranz 2000, 12). Sugihara posits two distinct types of industrialization, one a European-style capital-intensive industrialization, and another labor-intensive industrialization that was able to take root in

Asia because of its historical trends that produced a large, relatively skilled workforce (Sugihara 2007, 124). Hayami, for the Japanese case at least, calls this an "Industrious Revolution" in Asia after the fashion of DeVries (Hayami 2015).

As should be clear from the description so far, demographic arguments overlap in places with resource-based ones. The motivating factor behind demographic exhaustion is arable land, the fundamental natural resource for the simple Malthusian model of population growth. As Pomeranz notes, one of the classic types of Europe-centered stories pits an "ecologically played-out" East against a West that had room to grow, much of which was via colonization or exploitation of the new world (Pomeranz 2000, 10). This kind of ecological exhaustion argument may read back more contemporary East Asian ecological crises into the past, as Pomeranz claims, or simply turn a blind eye to the actual natural bounties of parts of Asia (Pomeranz 2000, 11-12). Given the comparable state of timber and soil between Europe and China, he argues, if China was 'falling' from ecological crises, then Europe should have been doing so as well.

The second type of ecological argument differs more fully from demography. It attempts to circumvent this problem of resource comparability by focusing on those few ecological features that are not consistent between Europe and East Asia, and here Pomeranz buys in, rather than dissents, from the natural resource-based arguments of others. What made the difference, in this vision, were "important and sharp discontinuities" coming from the accessibility of fossil fuels in England, and access to resources in the New World that were of an entirely different scale than was available within Europe or East Asia themselves (Pomeranz 2000, 13). Here, Pomeranz builds on Wrigley's work emphasizing the importance of coal to industrial take-off in England. Coal's primacy as a power source, over wood, is not necessarily clear based on its intrinsic material properties, and indeed it required in some cases decades of experimentation to be fully adapted as a fuel in industries, such as steel-making, where its impurities caused problems with the behavior of the product (Wrigley 2010, 100). Coal also has the potential disadvantage in that it is not generally available in the local environment, and so requires a developed transportation system to move the resource from its sources to its users (though this is itself a path-dependent characteristic, in that a transportation network developed to distribute coal may go on to boost later industrial productivity of all kinds).

However, coal's great advantage over prior sources of energy was in both its large absolute scale in terms of stored energy, and its even more massive scale when considered with respect to land area used. Coal provides, in Wrigley's terms, "ghost acres," vast swathes of land that would have been needed for trees had all the energy required by the industrialization come from firewood rather than fossil fuels (Wrigley 2010, 39). Coal is a punctiform, rather than areal, resource, coming from particular geographically confined locations rather than taking up large quantities of otherwise useful land—it is this fact of coal's material properties, in a sense, that allows a coal-fueled society to avoid, or at least put off, the Malthusian checks of land demand. Wrigley's central thesis in *Energy and the English Industrial Revolution* is that "the discovery of a way of meeting the energy needs of an economy from a single source which was not subject to the limitations associated with dependence on the annual round of plant photosynthesis, was the decisive step in ensuring that growth would not be halted by the changes induced by its earlier success" (Wrigley 2010, 100). The average coal miner could "produce" (unearth) 13 terajoules of energy annually, while each agriculturalist could produce only 0.10, a difference of two orders of magnitude (Wrigley 2010, 244)! From this comparison alone it is not hard to see how the energetic argument becomes an incredibly compelling one—especially as the changes we are attempting to explain are, as McCloskey is so fond of noting, changes of several orders of magnitude. The added benefit that coal freed up additional land for the production of other raw materials, along with the mass importation of such materials from the colonies, was able to push up the productivity ceiling, such that the newly energized industries did not simply run out of resources to process.

These properties were foremost in the minds of at least some economists as far back as 1865, when Jevons published *The Coal Question*, which begins: "Day by day it becomes more evident that the Coal we happily possess in excellent quality and abundance is the mainspring of modern material civilization" (Jevons 1965, 1). The energy dug up from the deep geological past makes "almost any feat" possible, and its lack would return us inevitably to the "laborious poverty of early times" (Jevons 1965, 2). So, as early as coal was identified as a potential source for a great unlocking of productive potential and a vast amelioration of living conditions for the general population, the inevitability of its eventual exhaustion has been a matter of great concern. This is the price of a highly productive consumptible, rather than fungible, society: consumptible resources, by their nature, are limited (Wrigley 2010, 22). The narrative of a coal-based Great Enrichment is not quite the simple one of a single great unlocking of productivity and an eventual collapse. As Wrigley is careful to note, coal was not a one-shot solution. Its widespread use came on the heels of other changes in transportation, such as in increase in the output of oats and the use of horses for agriculture and transportation, that magnified its impact (Wrigley 2010, 31). And the new transportation networks that trade in coal created went on to serve other purposes in aiding economic growth via the shipping of commodities. And as McCloskey notes, though resources are fundamentally finite—the Earth, or even the Solar System if one wants to draw the line that far out, is for most purposes a closed system; new resources do not enter and waste does not leave—what is considered a resource expands with technical progress, such that all past predictions of the exhaustion of our fossil fuels have proved false: highly-motivated economic actors have figured out ways to increase supply, or substitute alternatives (McCloskey 2016, 66). However, given that there are fundamental energetic and thermodynamic limits to life within our little closed system, such resource-based questions are matters of considerable debate and concern especially if they are what has uniquely allowed the Great Enrichment (see Meadows et al. 1972, Schumacher 1989). Debates about resource use and environmentalism and growth, can, mathematically, only ever turn out one way in the far future. But this mathematical limit is as intangible as it is fundamentally irrelevant: we are doomed no matter what, either by our own growth or the heat death of the universe; the only question is how long we have. The problems here turn ethical and philosophical.

But perhaps raw materials are not so important as these stories make out. Perhaps, given the right economic structures, growth will occur almost regardless of resources, as economic actors figure out the appropriate solutions to innovate around these difficulties. This type of explanation is that preferred by Braudel, Wallerstein, North, and Brenner in different ways. For Brenner in particular, institutional differences around the protection of private property rights made the difference for spurring economic growth. This differential is not simply an East-West one, about a West that protects private property and an East that does not—which as Pomeranz and McCloskey both note, though different ways, does not square with historical fact (Pomeranz 2000, 12–13; McCloskey 2016, 86). But it also interacts with class struggle so as to distinguish Britain, where industrialization began, from a France that lagged behind: while conflicts over property rights turned out to provide strength to small independent agriculturalists in France, they strengthened agricultural lords in England, which produced an unemployed ex-agricultural workforce freed to move to urban areas and become factory workers (Brenner 1982, 16–17). For Douglass North, by contrast, the distinction that made the difference was the presence in Western Europe of "increasingly competitive markets for commodified land, labor, capital, and intellectual property" (Pomeranz 2000, 15; see also North 1981). This take on the importance of institutions is not far from McCloskey's argument on its face, though McCloskey identifies the source of the institutional change within a broader force of changing ideas that had additional effects outside of institutions per-se. For Wallerstein, these institutional factors of free labor, capital markets, and government-favored reinvestment of profits combine to explain what make the "core" countries core, and these advantages are subsequently compounded by the central positioning of these nations within an international labor system (see Wallerstein 1974). N. F. R. Crafts, though he is primarily interested in how the English economy developed rather than why it was first to industrialize, finds that changes in urbanization, the distribution of the labor force, reinvestment of capital, and development of factories are all important signposts for the Industrial Revolution in England. In particular, the share of the agricultural labor force was exceptionally small, supporting the notion that the availability of industrial labor may have been a key contributor to the early industrialization of England (Crafts 1985, 61).

Rosenthal and Wong, in *Before and Beyond Divergence*, spend several chapters considering whether different institutions, or aspects of institutions, including capital markets and family structures, provided a relative boost to Europe, just as Pomeranz studied these factors before them. And their conclusion seems to be that in general, institutions were often less different between East and West than previously believed, and at any rate any differences are insufficient to explain a divergence. The sanctity of private property is a particularly played out explanation, to which McCloskey likes to reply that respect for private property is abundant in organized societies of even the ancient world because it is what we mean when we define a group as an organized society (McCloskey 2016, 86). Pomeranz does identify certain institutional patterns that separate out some areas of Europe, China, and Japan as most likely to be places where divergence begins, but they cannot explain why industrialization actually happened first in Europe (Pomeranz 2000, 24). The most compelling institutional difference that Rosenthal and Wong seem to come up with is a difference in the taxation schemes of Europe and China, which was, in their view, probably a net negative for the European economy at the time. However, they claim this may have provided an "irritant" to spur structural changes that China was later unable to cope with (Rosenthal and Wong 2011, 205-206). This is a different kind of path-dependent argument, which has something to do with Europe's fragmentation and history of internal warfare, but also has much to do, it seems, with the sort of Bourgeois Virtues wherein McCloskey finds the source of divergence. As Rosenthal and Wong note, good governance in Europe came to be identified not with low taxes per se, but "no taxation without representation," part of the traditional liberalism McCloskey identifies as the cause of divergence. Acemoglu and Robinson fall somewhere on this spectrum as well, essentially arguing that rapacious, extractive, and corrupt institutional structures are the cause of national failure. To hear them tell the story, the factors that have held nations such as Egypt from the prosperity of the West are the same things Egyptians themselves will tell you: "an ineffective and corrupt state and a society where they cannot use their talent, ambition, ingenuity, and what education they can get" (Acemoglu and Robinson 2012, 2). Representative institutions, or at least ones that are relatively un-corrupt, which generally are one and the same, make the difference between prosperity and poverty. When elites scrape away much of the nation's wealth for their own gain, societies cannot grow at Western rates. While Acemoglu and Robinson's arguments are directly founded in institutions, they are also on the border with the Bourgeois Virtues. High taxes differ from high appropriation due to the power of representation, which comes about due to certain cultural or political commitments. Institutions come about because of particular sets of ideas.

The last major class of explanations for the Great Divergence is therefore that of ideas. Was it perhaps inventiveness, innovation, and new classes of innovators, who provide the opportunity for divergence? Crafts disagrees with this concept, stating based on economic data about productivity growth (and directly contradicting McCloskey's 1981 *Enterprise and Trade in Victorian Britain: Essays in Historical Economics*) that it "does not seem appropriate to regard innovativeness as pervasive" in Britain during the Industrial Revolution (Crafts 1985, 87). However, Mokyr and McCloskey defend ideational arguments for the divergence. Mokyr's arguments are actually quite close to McCloskey's in many ways, though he focuses on an elite group of inventors rather than a change in the cultural evaluation of the bourgeois: in both cases, it is a new freedom to invent, and to profit from inventions, that opens the door to previously unheard of levels of economic growth

(Mokyr, 2005). And I think few would argue against the idea that technological advancement in capital-intensive industries had a lot to do with divergence in practice—in a very basic way, this is where the unprecedented surpluses allowing for growth came from. But among questions that remain, the precise causal mechanism is not certain. Was it ideas alone that caused a revolution? Or was the tumult of new inventions caused by, for example, the institutional factors that Crafts, North, and Wallerstein favor. And the question still remains, why Europe? Advanced science existed elsewhere, and the Enlightenment in Europe is not coextensive with changes in industrialization. McCloskey certainly favors the story that the relevant innovative ideas were freed up by another class of ideas entirely: a new "ideology of liberty and dignity" for common people that both brought them into the fold of invention from which they had previously been excluded, and made socially acceptable the maintenance of a culture of invention through the accumulation of commercial profit (McCloskey 2016, 21).

A careful read on the Bourgeois ideational hypothesis leads back toward the institutional explanations, however. When considered carefully, McCloskey's explanation, which depends on the R's of: Reading, Reformation, Revolt, Revolution, and the Reevaluation of the Bourgeoisie, is less about ideas springing forth from nothing than about a cultural or sociological context (McCloskey 2016, xxxv). Divergence in this theory is a matter of the "surprising, black swan luck of northwestern Europe's reaction to the turmoil of the early modern" (McCloskey 2016, xxxiv). Uniquely in this context, unlike Japan, China, or India, the main economies to which Europe is compared, Europe developed a set of ideas we recognize as liberalism—loosely: liberty, equality, fraternity—and its attendant economic pattern of "trade-tested betterment" in the McCloskeyan phrase. This was all a response to or a product of these five R's. McCloskey hews generally to the ideational hypothesis, but states that "ideas for the inventions [which unlocked a 70-fold betterment for most of the world's population] . . . were released for the first time by a new liberty and dignity for commoners" that was a product of these black swan events, which are not solely ideological things (McCloskey 2016, xiv). The desired level of explanation matters for whether this is considered to be growth as a consequence of ideas, or of political shifts. McCloskey writes about it as primarily a question of ideas even as these ideas are clearly intertwined with the institutional changes inherent in reformation, revolt, and revolution. Teasing these apart leads quickly into the realms of philosophy and unprovable historical counterfactuals about revolutions without changes in values, and changes in values without revolutions.

Recommendations from Divergence Stories

Most notably for our purposes, these different narratives of divergence drive different kinds of policy recommendations. If economic growth is considered to be, universally, a very good thing, in bringing increased prosperity to people—and especially if a lack of growth leads to dysfunction and economic collapse, due to the organization of markets around the production of value through growth—then different origin stories for the Great Divergence, based in different first principles, suggest different paths for the maintenance of growth in the more-developed world, and for the lifting up of the bottom billion people who have so far benefited the least from global economic growth.

Demographic explanations for the divergence suggest demographic solutions, which are fundamentally unsatisfying in a modern context. While Hajnal's data on European marriage patterns certainly suggests a culturally-based "solution" for lifting up the bottom billion, albeit essentially a product of Western cultural imperialism—encourage European-style marriage patterns, which should thereby stimulate savings and support the production of greater markets for consumer goods—it does not do us much good to diagnose contemporary economic ills in the more-developed world. Having already by definition instituted European marriage patterns, where would Europe go to unlock further growth? In the United States, marriage rates are decreasing, and average ages at marriage and proportion of people never marrying continue to increase, and yet these increases are not seeming to produce runaway economic growth (CDC 2012). Given contemporary data it seems most likely that if European marriage patterns are a part of the divergence story, they are a deeply contingent one, and one that acted only with other causes, rather than as the primary causal factor. Despite recent interest, demographic explanations are sufficiently out of favor in the economic history establishment that McCloskey does not even bother to address these arguments directly in *Bourgeois Equality*, even though she direct attacks arguments rooted in trickle-up, trickle-down, governmental, and institutional rhetorics. Perhaps marriage patterns favored certain economic developments, but they are not responsible for them, nor do they leave us room to explain continued economic growth beyond a simple step-based change. They may alter the baseline of economic activity, but it does not seem plausible to explain an exponential effect via this relatively limited shift, one which is linear with respect to time and population. If we leave Malthusian catastrophe behind, the demographic explanation essentially reduces to arguing that market-participating population is the growth determinant, which really puts us into the playground of institutional factors.

Resource-based explanations seem to have continued relevance to modern economies in a way that demographic explanations may not. Particularly compelling here is the energetic explanation in the tradition of Jevons, Wrigley, and to some extent Pomeranz. If coal as an energy source was at the center of a network of societal changes that made possible the growth of a market-consuming laboring class provided for, in essence, by the energy borrowed from the deep geological past, we now need to be concerned about sustaining this surge of energy. If it was a vast store of energy that made sustained growth possible, opening up new possibilities for mechanical work that were absent when all the energy consumed in a year had to be produced by the prior year's photosynthesis, how do we continue to secure such stores of energy to maintain growth into the future, without making the world an unlivable place? The pessimistic way to look at the energetic hypothesis is that our markets have ballooned on the borrowed time of non-replenishable, consumptible sources of energy, and we risk coming to a juncture in which we will have to renegotiate our sources of energy. If fossil fuels made the divergence possible, can their exhaustion unmake it? Or at the very least, if energy production threatens to return to an areal nature (via solar and wind power), albeit with greater efficiency than photosynthesis, Wrigley's book calls us to ask: Will the Ricardian pressures of land demand we have been escaping for hundreds of years yet have their revenge? In this view, growth continues due to our ability to expend increasing amounts of energy, and so what is needed to maintain growth in future is to continue the process of liberating greater and greater yearly amounts of energy from the environment. It may well be that the limits on this are high—commercial solar power is less than 20-percent efficient today, which gives plenty of space for science to improve energetic yields, and there is plenty of space left to put solar farms that is not particularly useful for other purposes—but they should at least be a concern (Martin 2016). The reserves of the necessary nonrenewable resources might become low, as Meadows et al. warned of in 1972, before we ever reach areal limits to energy generation (see e.g. Meadows et al. 1972, 66). But the resource hypothesis for growth provides both a clear path forward to maintain growth, one consistent with what the market is already doing (keep making greater supplies of energy available for industrial use), as well as a fundamental, resource-based set of limits on economic growth no matter what new technologies we are able to invent. The energetic narrative is largely an optimistic one, as there is nothing, short of a global Dark Age or the encounter of fundamental physical barriers to growth, that should arrest economic development once begun. Assuming climate changes can be avoided or adapted to, this explanation seems to provide a way forward.

Institutional arguments about the source of divergence present similar challenges, when applied to the present, to the demographic arguments already examined. If it was certain political or market structures that allowed for growth, then those structures need to be exported to the bottom billion. The historically fraught attempts to export Western economic success to Latin America through the implementation of import substitution industrialization fall into this mode. ISI sought to produce strong internal markets through government investment and Keynesian economic practices, but did not yield the desired results and is widely regarded as a failure (see e.g. Franko 2007). This failure was followed by the so-called Washington Consensus model for intervention, supported by the IMF and the World Bank, which essentially reads like a neoliberal economic wishlist: fiscal restraint, trade liberalization, privatization of state enterprise, and deregulation are among its primary components (see Williamson 2000). Whether or not these policies have been successful in the Latin American context is a subject of some debate, with Williamson himself suggesting that his term was never intended to imply the sort of extreme neoliberal policies that some have interpreted as being under its banner (Williamson 2002). The question of whether and why Latin American countries have failed to experience Euroamerican levels of economic growth might shed important light on the role of institutions in local contexts as determinants of growth, though a detailed treatment of that debate is beyond the bounds of this paper. However, institution explanations raise other questions within the Western context: the question, "Is growth at risk, and what do we do about it?" boils down to a question of whether the growth-producing economic conditions of strong markets, private property protection, and reinvestment of profits are maintained. Some particular threats stand out here: Crafts, in the conclusion to *British Economic Growth during the Industrial Revolution,* addresses the follow-on question of whether the British economy failed during the Victorian period, to which he answers a qualified yes. For McCloskey, British economic growth during this period seemed comparable to other advanced economies, but Crafts identifies other economic historians, including Allen, Berck, and Webb who criticize British industries with respect to their total factor productivity (McCloskey 1981; Crafts 1985, 157). Kennedy and Richardson likewise favor a view that Britain did indeed lag behind its potential because "resources were not deployed to exploit opportunities which did exist" (Kennedy 1974, 440), perhaps because the economy was "overcommitted" (Richardson 1967, 194) or perhaps for other structural reasons. Crafts suggests a path dependency, that the success of the early start locked in place a particular economic culture, and that perhaps Britain was unable to access a ″higher growth path based on the opening-up of higher returns to investment in education and science″ due to entrenched cultural factors (Crafts 1985, 160). Solutions to this structural inadequacy in the British economy seem to tend toward the ideational regime, e.g. a different cultural valuation of science education. Other threats issue straightforwardly from classical economic theory. If economic growth depends on the ″reinvestment of a sufficient fraction of [the economy's investible] surplus,″ then anything that stands in the way of such reinvestment is a grave concern (Eltis 2000, vii). This is in fact the concern for Louis Hyman, who in a 2016 presentation titled "Unnatural Capitalism: How the New Deal Reinvented Capitalism and Why We Need to Do It Again," argued that the United States has too much money sitting in banks, and is flirting with a repeat of the Great Depression if that money is not reinvested (Hyman 2016). The ills and solutions to institutional crises are, among our four classes of stories, those most clearly within the traditional realms of economic theory.

The ideational hypothesis for the Great Divergence instead suggests problems and solutions that rise above the details of implementation. If it is old-fashioned liberalism that is the heart of economic growth, as McCloskey asserts, then threats to economic growth are the same as the threats to liberalism, and the one goal for all those interested in human betterment is to ensure that liberal values triumph across the globe. Citing the "astonishing" results shown by India and China after accepting liberalism, she suggests that economic growth is not something to be chased directly through instrumental economic means but "something people and their countries do mostly on their own, by way of the liberating and dignifying trade-tested progress in a market stall or a little machine shop" (McCloskey 2016, 142). Though good and honest governments are rare, even corrupt and growth-draining governmental structures can be overcome in the presence of free markets and liberal values (McCloskey 2016, 140, 624-625). The ills and solutions look somewhat different for a Sweden or a South Africa: when a nation has already accepted liberalized trade and is doing well, even a high level of socialist welfare state practice is not causing that much harm in McCloskey's view; but for those nations who have not yet achieved the requisite levels of growth, hands-off economic policies are the necessary solution for taking the brakes off economic growth. And in either case, what is to be fought for and protected are the ideas that make the whole project possible. Were we to lose liberal values entirely, so McCloskey's narrative goes, we should see growth evaporate. Having eliminated other explanations, such as institutions and natural resources, as either too late, too weak, or as second-order outcomes of ideational change, McCloskey identifies the social ethics of liberalism as *the* factor to be nurtured and protected.

Enter Computation

One of the primary issues with comparing and evaluating these divergence narratives has been the problem of level of explanation. Demographic, institutional, resource-based, and ideational depictions sometimes differ more by a philosophical commitment to what can be considered a causal factor than the actual dynamics being explained. But this ambiguity is also a site for new interventions. Therefore, I would like to reimagine some of these arguments in a different mold, that of computation. It is possible to read portions of the resource, institution, and ideas arguments not as stories of the things in themselves, but as outgrowths of a great unlocking of human brainpower through competition, of devices and ideas, that essentially functions as a highly efficient distributed computing system. Culture, coal, and colonies all become linked through the notion of human society as essentially a large scale information processing endeavor. This perspective has roots both in cybernetics (another C-word, conveniently enough), which begins to view human brains as computational systems, and links them to other kinds of computational systems, both organic and inorganic (see for example Newell and Simon, 1957 in which the computational processes of the Logic Theorist program are explicitly analogized to those of the human mind); and in an understanding of the Smithian invisible hand as essentially a maximization process under constraints, and therefore interpretable as an algorithmic process. Stafford Beer imagined the complex ecosystem of a pond as essentially a distributing computing process, a slew of organisms acting simultaneously for their own ends, capable of being harnessed as a control system and used to manage industrial production (Pickering 2010, 2). While this enterprise was not successful, it represents a way of thinking about large scale distributed behaviors that remains relevant. Beer later applied the idea of cybernetics to develop a sort of radical socialist economic planning in Chile under Allende, though his control systems here were electronic rather than organic (Medina 2011). He did however envision using human beings as part of the control system in the form of "Project Cyberfolk," which collected opinions about the happiness of the Chilean people via so-called "algedonic" meters to be used to aid in the economic planning project (Medina 2011, 89). His inspiration, to use "the [human] brain as a computer, structured and programmed by individuality," to provide real-time feedback about how the system was operating, is particularly relevant to the notion of seeing independent human actions, properly harnessed, as a distributed computation (Medina 2011, 89). Herbert Simon, in his management science work, developed the idea of bounded rationality to describe human decision making: the decision maker is not a perfect information processor, but nonetheless the general scope of what he or she does is process information under constraints (Simon 1997, 291). And if the economic world is made up of a large collection of processors acting imperfectly based on incomplete local information, but manages to produce in the aggregate what largely appear to be “efficient” outcomes, then this looks like a distributed information processor that largely works quite well. Buoyed by advances in computational power, there have been discussions since the 1990s that a revival of cybernetic techniques of centralized economic control, like Beer’s Project Cybersyn, might be possible with contemporary computational resources, and might produce outcomes as good or better than the free market (see Cottrell and Cockshott 1993, Cottrell and Cockshott 1994). Whether or not this is true depends on what is gained and lost in the centralization of control, as compared with distributed economic decisions that may be locally efficient but impose some loss at the aggregate level. But at any rate, in the historical context of Cybernetics and rationalist economic modeling, it is not absurd to suggest that people coming together in markets of goods and ideas, through uncoerced liberal exchange, are joining themselves into what is essentially a society-sized information processor.

How does such an information processor function, and maintain coherence? Since Shannon and Weaver’s *Mathematical Theory of Communication*, it has been possible to conceive of at least some aspects of human communicative behavior as *communication*, in the formal sense of information transfer. Much hinges on the definition of information, and this does not necessarily include all aspects of human speech. But all manner of economic statements are well within the bounds of the information processing paradigm: “X’s are worth Y” or “I will purchase W Zs” certainly qualify, as do more complex statements like "take two aspirin, and call me in the morning." And the production and weaving together of these statements into patterns of behavior—the inventing, producing, purchasing and consuming of the talked-about products—depends on the collectively harnessed action of individual human minds. There is a comforting naturalness to the view of economic growth as a product of collective human brainpower. It aligns with the fundamental claims of McCloskey's *Bourgeois Virtues*. Trade-tested betterment is a process that relies on profit as the heuristic of goodness; profit means do more of this, loss means do less of that. The articulation of what to do therefore "comes from the dollar votes of ordinary people, a democracy of what people in aggregate are willing to pay" (McCloskey 2016, 565). Deciding what to pay is an information process, a weighing of costs and benefits: computation at its finest, salted with a liberal helping of psychology, consumerism, impulse buying, and retail therapy. And the market system, in linking many of these individual computations together, builds a distributed computation system that "calculates" the appropriate price, allowing for human foibles in the process.

To say that growth is about computation is not to say humans have changed. It is not that we have become substantially smarter over the past two centuries in any sort of biological way. Improvements on IQ tests are the result not of genetic improvements but increased training in the type of analytical thinking tested for on IQ tests (see e.g. Wicherts et al. 2004). The unlocked success is not about the abilities of individuals, which were always there, but the opportunities for them to exercise those abilities (McCloskey 2016, 474). Brainpower that was once wasted, or whose fruits were ignored as sinful or worthless, finally achieves a life-sustaining commercial outlet. While the great masses of humanity lived a meagre existence, trodden into the dirt generation after generation, only an aristocratic few produced society's ideas, and many of these (Sorry, Socrates; forgive us, Leonardo; mea culpa, Galileo) either hid their ideas or found themselves persecuted for them. And these ideas, tested as they might have been by philosophy, science, and the arts, were not put to tests that pushed them to be useful at producing surplus, or perish. (This surplus test was good for human welfare, though whether or not such a perspective is a good thing for the arts, or for example, the modern public university, is another question.) McCloskey's "sweet talk," which is a large, increasing, and formerly neglected portion of the economy, seems to be the communications protocol by which this trade-tested betterment is orchestrated—deciding what is to be done, connecting buyers and sellers, convincing them to make deals, directing them at what books to read, chiding them to eat their vegetables. This talk is not obviously computational, to the layperson; but it does transfer information, in that it structures the actions of individuals and thereby acts as the behavioral glue that holds the whole structure together. So to the information theorist, networks of talk can be networks of computation. To view the Great Divergence as computational is essentially to accept McCloskey's premise that all depends on the dignity of the trade test and the dignity of the common people engaged in the practice, whose brainpower, however large or small individually, contributes just one more little input to move the market in the appropriate direction.

As discussed, this computational explanation fits with contemporary ideas about complex systems, and humans as essentially organic computers. And it is also in line with some previous scholarship on industrialization, including Beniger's deeply ambitious *The Control Revolution*, which attempts to write the entire history of life itself, from bacteria to Boeing 747s, as a process of exerting control over longer distances at greater speed. Here, Beniger draws from the intellectual tradition of the likes of Lewis Mumford, who in *Technics and Human Development* wrote that the primary, contemporary advancement (not a *good* thing, mind you) of the "megamachine" has been the replacing of "recalcitrant and uncertain human components with specialized mechanisms of precision made of metal, glass, or plastics," and thereby "Power, speed, motion, standardization, mass production, quantification, regimentation, precision, uniformity, astronomical regularity, control, above all control—these became the passwords of modern society in the new Western style" (Mumford 1967, 294). Mumford's megamachine originally existed in antiquity, as a mechanism of centralized control for large collections of human beings responsible for building the great works of the Ancient World, like the pyramids. And this sort of control does fit into the mold of computation and information processing as conceived here. But the new, faster, more powerful version of the megamachine brings with it new capabilities of mass production for mass society. Likewise, for Beniger, the Industrial Revolution was essentially caused by increases in the speed of transmission of goods and ideas. His chain of causation touches upon many of the levels we have already seen: new sources of energy, among other things, sped up the "entire societal processing system" and thereby put "unprecedented strain" on all the "technological and economic means by which a society controls throughputs to its material economy" (Beniger 1986, 218). The "continuing resolution of these crises" of control resulted in advances in communication technology, from trains to telegraphs to modern information technology, that supported the increased energy utilization and processing speed that have made the modern world what it is (Beinger 1986, 218, 293). So this too is a technical-ideational explanation, in the mold of previous scholarship discussed here. Meanwhile, advances in marketing and the production of a mass market, and advances in data processing and bureaucratic control of organizations, make clear that control is aligned with our notion of computation. Like the efficiency of the market, advances in control are outcomes of distributed systems acting in their own interests (something Beniger roots, rather loosely, in processes of evolution and natural selection). Control is expressed in the form of the "twin activities of information processing and reciprocal communication," explicitly informational and thereby computational in our usage (Beniger 1986, 434). Innovation is, he writes, "increasingly a collective, cumulative effort," and therefore technologies of storage and retrieval of information are advanced to serve this need by linking together the capacities of many individuals in more efficient ways (Beniger 1986, 434). While I am skeptical of the value of Beniger's broad historical scope, and find his reaching back to bacteria and evolutionary selection to be a risky and ill-founded enterprise, much of what he describes in the era of Industrial Revolution, and subsequent "Control Revolution," fits with other histories of organizational technologies (see e.g. Yates 1989).

Computation as a Model for Growth

So the literature is behind this computational narrative. But what new perspective does it provide us? Like each of the other divergence stories, computation presents its own read on the economic questions of interest. If one were to write out a set of equations for the networked, distributed computation model for economic growth, it might look something like this:

$$C_{material} \sim N\,P + N\,n\,T$$

$$C_{cognitive} \sim N\,n\,S\,E\,\gamma$$

$$G = \alpha\ C_{material} + \beta\ C_{cognitive} + K$$

Here, the two C factors are the human components to growth, one in terms of material things and the other in terms of ideas; N is the size of the human informational network (number of people connected); P is an average measure of material productivity of each connected person (which includes the impact of machine labor and computational tools used directly by the laborer); n is a measure of network density (number of connections per person); T is a McCloskeyan "sweet talk" factor, that measures the sophistication and effectiveness of sweet talk in transactions of goods (which also may involve computational tools used by the laborer to further these exchanges); S is the speed and productivity of connections in the network (which depends on properties of the information channels used); E measures the accumulated skills and education of the participants in the network; γ is a possible difficulty scale factor to deflate this innovation term (if one accepts the idea that innovations get progressively more difficult to achieve over time); K is a term to express the impact of artificial computational power hooked up to these networks in the appropriate way, not directly operating through human participants (think Beer's Project Cybersyn), and G is total economic growth. Alpha and beta are unknown scale factors, and indeed there may be terms missing, and other scale factors involved that are not provided in this sketch. But as a rough model, this relationship of terms provides certain predictions that are directly in line with historical evidence, and the other notions of the Great Divergence surveyed above.

As general trends, this model predicts we would see that growth increases where: more people are connected to each other in dense networks (N and n); material productivity per person increases (*P*); speed of transmission of ideas increases (*S*); exchanges happen more smoothly or readily (*T*); people have greater education and skills (*E*); and artificial computational power included in these networks increases (*K*). Of these, the only claim unsupported by existing data is the last one—trivially, because this model was built directly from the claims of the other four divergence narratives. But what this model provides is comparability of the *K* factor to the rest of growth. Just as human brainpower needs to be "hooked together" in the right way, via networks of exchange, computers might be hooked to the economy in the "right way" to contribute to these networks in a largely independent way. We have no good model, yet, for what this *K* component really represents. Beer's Cybersyn project would be included here, had it remained in operation. It is possible that high-frequency trading technologies are included in this term as well; though managed and surveyed by people, computers that automatically make trades on the stock market start to suggest the kind of independent action that would support pulling them out of the human-network terms. But there is nothing fundamental about human beings as information processors that allows us to rule out the existence of such a term, in the computational hypothesis. Because of its construction, our model of growth should show continuity between the Industrial Revolution and the Control Revolution/IT Revolution, though the size of the *K* parameter may be increasing over time. The key question presented is the size of that term.

The computational explanation has advantages over other portrayals examined here, in that it provides a framework in which to unify market demography, the transmission of goods, and the transmission of ideas as economic actions responsible for betterment. It depends on the dense market connections between people that are supported by scholars of the European marriage pattern, but it does not present a Malthusian paradox. The model is not necessarily dominated by N alone, if it comes at the cost of advances in productivity (and indeed a large population, but low market-participating population, would present a low N in this model anyway). Computation presents a more fundamental cause than resources alone (which are not fixed, but expand in type and efficacy with ideas about how to harness them), or institutions (which depend on cultures, including flows of ideas, to function). And computation is less general than cultures (nebulous and difficult to define) or ideas (which ideas, and what did they do?) alone. It provides a structure to the relevant components, and a direct way to link them to outcomes through distributed processes of decision making. It also takes seriously the notion that much economic work is sociomaterially performative; that stories, speech acts, and practices create reality. Ben Bernanke, hardly a bastion of postmodern thought, has oft repeated that 98% of monetary policy is talk, creating the stories that economic actors will follow (Bernanke 2015). And a computational/information processing model of growth actually manages to account for the labor of sweet talking. This much is essentially McCloskey's argument in different terms. But the recognition that the ideational hypothesis really describes a distributed computational system leads to different considerations for the future. Protecting liberalism alone, to harness the decision-making powers of human beings en-masse, is no longer the only way to proceed. For much of history, human beings have been the most powerful information processors on Earth (Timmer 2011). The billions of us, taken together, still are. But between the slow successes of artificial intelligence and the expansion of inorganic computation in line with Moore's performative heuristic (I shall not call it a "law")—and new developments in quantum computers, biological computers, and other modes of calculation, that may extend that trend—it is possible that our computing power will one day be eclipsed. At the very least we have greater and greater reserves of non-human calculating power to draw from, which is part of what Beniger's Control Revolution concept is all about. We should see increases in economic growth with increasing involvement of information technologies, either through increased productivity of human beings or through new structures of information processing and market control: K. The increases in growth will not be near the total increase in computational power, because not all this power is harnessed toward economic ends. And not all growth that is due to the harnessing of artificial computation will reside in the K term, as some is hidden within P, T, and S. But if K is increasing, does this mean that humans' role in driving economic growth might also be on the wane? Can additional computation power speed growth further? And do we need liberal trade-tested betterment, or can we substitute for it artificially, in a computationally advanced planned economy?

Automation and the Future of Labor

Ideas matter. I do not argue with McCloskey's thesis. But ideas matter most strongly in particular ways. Liberalism in particular matters for growth because it triggers tinkering, sharing, and entrepreneurship, and because it produces mass markets and mass consumption to support this entrepreneurship. Reframing the ideational hypothesis as essentially a computational one reorients focus away from the distracting questions of what power ideas have over material circumstances, and toward the particular kinds of cognitive and cognitively supported labor that other historians and economists have already connected to economic performance. The computational approach highlights trade and invention. If changes in ideas were limited to philosophical or aesthetic pursuits, or if they were simply about new ways to consume coffee or chintz, they would not have had the effect that they did. The power of ideas comes in the linking together of large numbers of people in relationships of essentially mutual advantage, across a broad range of industries, and of incentivizing new and more efficient ways of performing these relationships. Under the computational hypothesis for the Great Divergence, the primary trade-off for continued growth seems to be one of advancing liberalism (the C terms) or expanding technocracy (the K term). Two arguments can be made. In the conventional case, what is necessary is to protect the gains we have made in trade-tested betterment in the developed world and to expand these gains to the bottom billion. In the other case, what is necessary is to increase the joint cognitive power of all economies, more and less developed. Education alone is not enough, without the mechanisms to link the educated together into productive networks. But to the extent that artificial computational power can perform the same decision-making roles that McCloskey's liberalized bourgeoisie do, new computer technologies stand to assist in this process in a way that is unlike the conventional view, in which they are simply the helpful outputs of a liberal society. Computation as a potentially "exogenous" growth factor—certainly human-created but acting independently of individual human actors' decision making—is not something McCloskey's model considers. While technocratic experiments in governance do not have the best track record (e.g. rationalized urban planning), and computation is not a cure-all, this discourse of computational betterment is nascent within the projects of machine learning, "Big Data," and the "Internet of Things." Smart things everywhere, processing greater amounts of data more effectively, appear as *the* technocratic solution par excellence of the last decade. The source of the missing masses of the economic growth literature, the component deeply studied at a micro level but largely unacknowledged at the scale of global economic history, may be the distributed computational power of human groups.

The computational hypothesis puts somewhat of a sunny face on automation—automation can lead to the increase of *K*, and thereby cause growth, regardless of what happens with the human-based *C* components. But growth as an outcome of increased computation still falls down, as a humane project, in the same places that growth from liberal ideas does: people who cannot participate in the marketplace are in trouble. They do not make income, and cannot afford the necessities of life, let alone the expanding range of goods and services that is the product of the growing economy we might wish to preserve and extend through automation. The causes of this failure to make one's way in the marketplace can be of many kinds—disability, a lack of education and skills, skills mismatched with available jobs, various structural reasons like poverty, incarceration, etc.—and independently, such issues are lamentable. But in bulk they threaten to undermine the entire system. Structural unemployment by way of automation presents a potential existential threat, even in a *K*-dominated growth model. McCloskey is perhaps a bit cavalier about the relationship between machines and jobs. Consensus of historians of technology seems to be that automation has, at worst, created *nearly* as many jobs as it has eliminated (and the vast expansion of the IT industries in the United States suggests that, indeed, many *good* jobs have been created by contemporary automation), but there is no guarantee that this will continue (Nye 2013, 161-164; Noble 1984, 330; Diebold 1953, 63-64). And the jobs that have been created have tended to be polarized, either lower or higher in skill and pay, than the jobs that were eliminated (Ford, 50). Though to McCloskey, "robots are merely mechanical slaves for our benefit," the *our* this statement refers to is not necessarily the whole of humanity, but only those people who can take advantage of the labor of machines (McCloskey 2016, 497). She argues that "Deciding what to do cannot in the end be mechanized . . . because the argument about what to do is never ended" (McCloskey 2016, 498). This seems accurate for at least a certain segment of the population—those fortunate enough to possess a graduate degree in Economics from Harvard University, for instance. But it emphatically does not mean that everyone can engage in the argument about what to do. Will the jobs be there for people who need them? Who will pay all these people for all this sweet talking, regardless of their skills?

Lewis Mumford smartly commented that the old dream to abolish all labor and replace it with automation, indeed one way out of poverty and toil, is a desperate and "unimaginative" one (Mumford 1967, 241-242). "It ignored the fact that work which is not confined to the muscles, but incorporates all the functions of the mind, is not a curse but a blessing. No one who has ever found his life-work and tasted its reward would entertain such a fantasy, for it would mean suicide" (Mumford 1967, 242). There will always be jobs for some people, those capable of using technology, of competing in the liberal marketplace of ideas. But jobs for everyone are not guaranteed. They never have been. But particularly if the computational explanation is right, and a declining human participation in the intellectual economy that sustains growth can be compensated for by increasing machinic participation, then the assumption that the liberal tide lifts all boats may no longer be valid. Growth could be maintained overall even while labor force participation declines, and an increasing section of the workforce is left behind.

The world in which machines contribute to the economy in precisely the same way that people do, thereby maintaining the old status-quo, is not the world we see today, or can expect to see. So instead of the productive "ghost acres" made possible by coal, we might be living in the age of legions of "ghost producers" whose limited material needs can eventually be met by a fraction of human society. None of the economic growth hypotheses, not demographics, resources, institutions, ideas, or computation, can guarantee an escape from the constant problem of who is able to benefit. While liberalism may have done a better job so far than other social organizations, there is no reason to think it is proof against technological changes. Thinking about growth as the output of a distributed information-processing and problem-solving process has the potential to put humans and machines on more equal footing in our calculations, and thereby do a better job of assessing what the impacts of computing really are. If K remains marginal, this model does little but attempt to make McCloskey's ideational hypothesis explicit about how we get from ideas to growth. And if K is large, humans are still not guaranteed the jobs they need to either afford goods or find meaning in lives culturally defined around occupations. But there is hope here, in this otherwise perhaps dismal picture. If the computational model is right, then growth *can* be maintained in the long term even with a decline of participation in the labor force. The K term can grow larger, while the other terms decrease. This change would come with great unrest. Dealing with such an economy will require structural changes to society: something like a universal basic income becomes a necessity if most people's participation in liberalized trade is not possible. But, on the plus side, such a switch to universal income and high unemployment—in the traditional sense of unemployment—would not necessarily set the economy into a death spiral from which it would not recover. In this model, it appears entirely feasible to maintain growth and humane distribution of the necessities of life; so long as *K/N* is large enough, there is sufficient material wealth to go around that everyone can be provided for at some reasonable standard. And there may be a second light at the end of the tunnel. Freed from the need to contribute to $C_{material}$ in order to survive—and freed, in McCloskey's terms, from the tyranny of the profane *P*'s—a society that made this transition could put more of its resources elsewhere, into $C_{cognitive}$ and the sacred *S*'s that provide new opportunities for meaning in a changed landscape of production. This is not Mumford's feared abolition of labor, but a possible demobilization of human beings from the confinement and regimentation of the megamachine.

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