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Will AI Generate a New Schumpeterian Growth Wave?

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Fifty years after Intel launched the microprocessor (1971) and Stanley Cohen and Herbert Boyer published the recombinant-DNA mechanism (1973) at the heart of "Biotech 1.0," the age of cheap computing, expensive biosimilar drugs, and genetically modified organisms is coming to a close. What new general-purpose technologies might replace these engines of growth? What kinds of social and political arrangements will support or impede the emergence and deployment of those new technologies?

That we stand in the midst of a geoeconomic and geopolitical inflection point is increasingly clear, but as Walter Benjamin said, the angel of history always looks backwards. Not being angels, we lean on our asset management expertise to take the riskier path of looking forward and sketching some possible scenarios for the post-inflection future. Doing so requires outlining growth waves in capitalist economies, first generally, and then specifically for the information and communications technology (ICT) plus biotech 1.0 growth wave to understand how an internal process of decay exhausted that wave, creating the forces generating the current inflection point. This clears the way to look at a potential new package of general-purpose technologies, why those technologies and organizational formats look like solutions to current problems, and how they might get married to emerging forms of corporate and social organization. We end with three scenarios for the future. Place your bets.

Growth Waves in Economic History

Joseph Schumpeter famously argued (and contemporary neo-Schumpeterians like Carlota Perez maintain) that orthodox economics gets things wrong by focusing on equilibrium models (as in the Dynamic Stochastic General Equilibrium models most macroeconomics deploys) and on exchange rather than on production. Instead, Schumpeterians view capitalism as a dynamic process that never attains equilibrium. Moreover, revolutions in productive technologies that create eras of relatively fast growth and then stagnation characterize capitalism more so than equilibrium. These technologies emerge as a package of investment-driven changes to how things are made, moved, and marketed.

Schumpeter identified four periods of rapid growth characterized by six big technological developments: (1) A new source of cheap energy, as with coal in the mid- to late nineteenth century or oil in the mid-twentieth century. (2) A new production process based on a new general-purpose technology, as with continuous flow production, and then continuous flow assembly line production using electrically powered equipment. (3) New investment or mass consumption goods, as with steel and then standardized consumer durables. (4) A new mode of transportation, as with steel steamships and bicycles, and then automobiles and aircraft. (5) A new form of corporate organization, as with the proliferation of vertically integrated firms with ownership divorced from management and then Alfred Chandler's "M-form"[1] multidivisional firm; related to that, new modes for financing investment. (6) Less salient in Schumpeter but nonetheless very important, as Perez has argued, new modes of social and economic governance to balance supply and demand, as with early twentieth-century cartels and then the post-1945 "Keynesian welfare states."[2]

Perez expands Schumpeter's "made, moved, and marketed" growth wave model by adding in "macro-managing" and "mindset"—that is, social dimensions like the congealing of common sense around "best production practices," corporate organization, financing, lifestyles, and macroeconomic management. She calls the resulting package—making, moving, marketing, macro-managing, and mindset—a "techno-

economic paradigm." Each new techno-economic paradigm manifests as rapidly expanding firms, whose investments and increased sales drive economic growth, until stagnation and decline eventually set in.

Consider the entire package of petroleum-fueled, mass-produced automobiles or consumer durables more generally (in Schumpeter's fourth growth wave), or ICT and biotech 1.0 (in what Perez identifies as our fifth, contemporary wave). Looking at things this way divides economic growth since 1800 into six identifiable eras based on both hard and social technologies, which figure 1 displays.

The fifth, current techno-economic paradigm began in 1971 with Intel's first microprocessor, though computing would take decades to achieve macro significance. The consistently falling costs of semiconductors opened up increasingly vast fields for the computing, electronics, and software industries. The chemical engineering skills of the electronics, and specifically semiconductor, industry also fed into the pharma sector's role in growth over this period. The exemplary consumer product of this era is the smartphone, which combines all prior major electronics, communications, and computing equipment into one device.[3] The Cohen and Boyer recombinant DNA process also opened up an era of bioengineering, replacing traditional drug research and plant breeding or hybridization methods with a relatively more targeted manipulation of genomes. Boyer would later help found Genentech, the first of a wave of new biotech firms in the pharmaceutical and agricultural space. Here, exemplary products were human insulin and herbicide-resistant soybeans.

FIGURE 1. HISTORICAL GROWTH WAVES

	General-purpose technologies	Energy source	Transport mode	Financial innovation
First Industrial Revolution, 1771–1828	Factory production, mechanization of textiles production	Water	Canals	Private banks & local networks (e.g. Quakers in UK, notaries in France)
Railroad era, 1829–1873	Metal machinery, steam engines	Coal	Railroads	State investment subsidies & public debt
First globalization era, 1874–1913	Bessemer and open-hearth furnaces; continuous flow production	Fossil fuel, electricity for transport	Steamships, urban trams & bicycles	Corporations & open capital markets
Automobile era, 1914–1970	Continuous flow assembly line, standardization, mass production	Petroleum, electric motors	Cars, trucks, and airplanes	State investment subsidies; public banks; segmented financial markets
ICT wave & second globalization era, 1971–2020	Semiconductors & software; recombinant DNA	"Negawatts" & petroleum	Telecommunications & containerization	Venture capital; securitization; institutional investors
Potential sixth wave, 2021–?	Bio-genomics, CRISPR, AI- & algorithm enabled manufacturing	Renewable electricity	Electrified vehicles	Private equity & private credit (?); overt state industrial policy subsidies

As Max Weber might put it, these technologies were ethically neutral. What was crucial was the new form of corporate organization wrapped around these technologies, because that drove growth while changing the distribution of income and production globally. U.S. courts and Congress, pressured by litigants in the new knowledge sectors (and some old sectors, such as hospitality), generated a series of changes in U.S. law around vertical ties and intellectual property (IP) rights. The Reagan administration's weakening of protections for unions and legal victories for the International Franchise Association were integral to the development of the current paradigm.[4] Changes to American franchise law meant that leading firms exercising high levels of control over their various suppliers would no longer be ruled illegal on antitrust grounds. The application of IP law to software, more robust trademark protection, extended copyright lengths, and the export of U.S. IP legal protection to other economies through trade deals also underpinned the success of corporate strategies focused on generating profit from IP ownership.

Franchises became the dominant form of corporate organization in this era. The old, vertically integrated firm structure gave way to a de jure vertically disintegrated tripartite structure that could take domestic or global expression. Three types of firms populated that structure. Lead firms, which often exercised de facto control over the entire chain, possessed significant human capital in a relatively small number of (highly compensated) employees, and used them to generate a colossal IP portfolio.[5] These firms then outsourced much of their production to two kinds of firms: second-layer firms, which are more capital-intensive, and third-layer firms, which are labor-intensive and produce undifferentiated goods and services.

Disintegration and the barriers to entry that intellectual property rights create allow the lead firms to control the vast bulk of activity in their value chains and appropriate the bulk of profits, while minimizing the risks of holding physical capital or employing legions of workers. Apple and its supplier relationships represent perhaps the most well-known example of this, but the model is also well developed in much of the pharma industry and the hospitality industry. Finance played a dual role in the ICT era, first taking on franchise characteristics itself and, second, facilitating the mergers and acquisitions that bolstered lead firms' control over the lower layers. Jack Welch's General Electric is perhaps the paradigmatic firm of this era, demonstrating both the superior profitability of this new mode of organization to wider corporate America in the 1980s and '90s, and the longer-term sources of endogenous decay that hollowed out the ICT growth wave.

The global communications infrastructure of the internet and the transport economies of scale achieved by containerization enabled the shift to this new production structure. These innovations made it easier and more profitable for firms to outsource labor and manufacturing. This is part of why the tripartite industrial structure of the franchise economy is globally distributed. The leading firms are located chiefly (but certainly not exclusively) in some areas of the United States; more capital-intensive manufacturing firms are found chiefly in Japan, Europe, and portions of China, and more labor-intensive manufacturing and services firms are located in emerging and frontier markets. At the same time, of course, the tripartite structure is also replicated within countries, including the United States. Apple's relationships with physical suppliers Qualcomm and Corning, and its contract service suppliers that provide labor for its headquarters, are examples of this dynamic.

IP-dominated sectors generally see powerful increasing returns to scale, which are one of the main factors contributing both to growth and the endogenous decay of growth. These returns to scale come partially from the near-zero marginal cost of distribution (the bulk of the cost comes from the IP development, whether that's a search engine algorithm or an antibody-based drug that treats arthritis). This contributes to the tendency for the franchise economy to have lower investment rates; franchise- and IP-based firms need to invest less than the historical norm to maintain their competitive position. It

also explains why much of the leading firms' investment means spending on R&D salaries to generate intangible assets. In this paradigm, investment often means higher wages for high-income professionals with relatively low marginal propensities to consume. This leads to lower spillovers into growth and the wider labor market than investment in expanding physical capacity. An Oxford INET paper on the causes of the productivity slowdown makes the same case, with the authors highlighting "lower spillovers from the growth of intangible capital" as one of the key factors in the productivity slowdown experienced in the second half of the current growth paradigm.[6]

Overall, the tripartite structure of the franchise economy combined with leading firms' low tendency to invest has created a long-term bias toward weaker labor markets and lower investment. This came alongside a falling labor share of income, as income increasingly went to asset-light, low-headcount, IP-owning firms with no incentive to redistribute this to a macroeconomically significant size workforce—in contrast to the prior mass production era. These characteristics gave us weaker growth and lower inflation, especially in the last two decades before Covid-19.

The Crashing of the ICT Growth Wave

Each techno-economic paradigm is underpinned by the increasingly intense use of an initially abundant and cheap core input and some dominant corporate practice. A crucial part of the exhaustion and death of a paradigm is that these inputs and strategies become depleted.

Take the case of vertically integrated, unionized assembly line production in the fourth paradigm. As growing numbers of firms adopted this model, profits declined due to the increasing saturation of markets and because standardization eroded competitive moats. Workers also began fighting the monotony and strenuous pace of assembly lines. Simultaneously, decolonization saw oil exporters form OPEC as part of an effort to enjoy the income stabilization seen by developed-economy workers and commodity producers (especially farmers).[7] Effectively, once the entire rich-economy world adopted the Fordist production structure, the world ran out of the cheap oil and docile semi-skilled assembly-line workers that this form of production required.

Generalizing this pattern, all paradigms experience endogenous decay: the process by which the relationships of exploitation that underpin a paradigm stop working and begin to push against it. This forces a period of crisis and change, which shapes the next wave of technological development that underpins the subsequent growth wave.

The leading industries of the fifth paradigm appear to be reaching saturation. Electronics, especially computers and smartphones, are the central industry of the fifth paradigm. Smartphone unit sales peaked in 2018. Growth now comes from price rather than volume increases and is tied to global population growth rather than the explosive expansion of new markets. Similarly, digital advertising underpinned the growth of the digital giants but (outside of streaming TV) is now a mature market. The maturity of the smartphone market and its related stream of advertising revenues can be seen in the wave of share buybacks undertaken by the big lead firms in that space: from June 2023 to June 2024, Apple, Alphabet, Meta, and Microsoft collectively announced share buybacks totaling $191 billion dollars, rather than investing in new output.

On the supply side, performance and pricing improvements in semiconductors are decelerating. Designing and building new, more powerful chips is increasingly resource intensive, as constructing next-generation chips requires smaller and more complex elements. Until 2014, Moore's Law produced consistently falling costs per transistor gate on a chip, but physical restrictions mean this no longer holds. Similarly, new semiconductor fabrication plants cost increasingly outlandish amounts to build. In 2023, Boston Consulting Group estimated that building a fab now requires $18 billion in capital

expenditures.[8] Unsurprisingly, new construction overwhelmingly relies on significant government subsidies.

Similar problems beset pharmaceuticals. Drug discovery costs have significantly increased, with some estimates suggesting that they increased over six times between the 1980s and 2000s (multiples above the overall price level increase).[9] Spending on drug R&D has likewise increased significantly—up about 250 percent from 2000 to 2018. New drug approval rates, however, are effectively unchanged.[10] Newer drugs are often biologics with far improved efficacy compared to traditional small molecules, but they are extremely expensive. Providing these drugs en masse is extremely challenging in the context of an intellectual property regime that allows firms a monopoly (and monopoly profits) on specific drugs, especially when relatively stagnant wages must fund taxes for public health systems or private insurance premiums.

Finally, this current paradigm is reaching social and political exhaustion. The success of neoliberalism in raising inequality, reducing income stabilization, and increasing returns on wealth (all as the Mont Pelerin Society wished) has generated a wide social divide centered around asset ownership. This discontent finds political expression in growing political dysfunction and polarization.[11] Polling repeatedly shows relatively bipartisan support for anti-monopoly policy.[12] This is not only influencing Democrats, but also traditionally less receptive Republicans—with Republican vice-presidential nominee JD Vance praising the antitrust work of Democrat Lina Khan's Federal Trade Commission.[13]

The global tripartite firm structure is also under attack, with bipartisan hostility to unrestricted trade with China and broad support for a return to protectionism. China's dominance of physical production has motivated an American and, to a lesser degree, European industrial policy response, as well as rising adoption of protectionist policies in the larger economies of the Global South. The current debate in the United States is more about how far this should go, not whether it should happen. Export controls intended to restrict China's technological capacity in key industries, primarily semiconductors, have cross-party support, as do industrial policies and subsidies meant to enhance domestic manufacturing capacity in strategic industries. This trend reflects the general acceptance within Washington that the United States is engaged in a long-term, strategic competition with China. In the 1960s and '70s, the U.S. government engineered a similar industrial policy response to rising European and Japanese competition in the production of physical goods, as well as the Soviet Union's rising share of global production of basic materials like steel. This industrial policy produced the IP-cum-ICT economy. It appears that geopolitical competition today is once again encouraging the production basis for a new Schumpeterian growth wave.

The fifth growth wave also faces a multipronged energy challenge. First, geopolitical shifts, such as Russia's invasion of Ukraine, have upended long-standing energy relationships. There are even tentative signs of a partial Saudi realignment, as seen in the late 2022 and 2023 OPEC production cuts that provoked horror and anger in the Biden administration as it grappled with inflation. China's dominance of clean-energy supply chains has also become a cause of concern in the United States. Over the longer term, the consequences of climate change are becoming increasingly visible and costly. Putting this in orthodox terms, you might say the unpriced climate externalities that have underpinned capitalist growth in every paradigm since the industrial revolution are beginning to show their cost at the systemic level.

Population aging and declining fertility rates also generate a final physical limit on the fifth paradigm. These trends are limiting the supply of cheap, mostly Asian, labor that powered the offshoring of third-layer labor-intensive production. Many Asian economies are likely to experience a steady decline in their economic growth in the coming decades simply due to their aging populations.[14] Much the same is true across the richest economies, with the United States faring better due to higher historical immigration

but still challenged. The pandemic has exacerbated this trend, though it began much earlier. The rising dependency ratio that results from an aging population can undermine the fifth paradigm model by strengthening workers at the expense of employers.

What Might Come Next?

Put simply, the technologies that might power a new growth wave are already visible: renewable energy for electrification of the economy; labor saving AI; AI-generated possibilities for new materials; a second biotech revolution in the form of CRISPR-Cas, mRNA, and other recombinant technologies guided by AI-enhanced genomics. But as noted above, the critical issue is not only the technologies themselves, but by whom, how, and how fast they are implemented. That is, the social aspects matter as much, if not more, than the hard technological aspects in determining the larger techno-economic paradigm that emerges around new technologies.

One response of capitalists to increasingly expensive labor is automation. Last year, Goldman Sachs analysts estimated that AI could automate about a quarter of total current work in the United States and EU.[15] That estimate is likely on the optimistic side, but AI enhancing labor productivity could provide a response to higher dependency ratios.

AI provides a new growth area for healthcare, offering a potential path out of the challenges of the current growth wave. The rapidly falling cost of genetic sequencing combined with Google's AlphaFold 3, which can accurately predict the shape of specific proteins including DNA, RNA, and ligands, opens up the possibility of new small molecule drugs and biosimilars. Sequencing allows confirmation of the shapes that AlphaFold predicts, and with CRISPR-Cas and mRNA, these proteins can be built. This unlocks a new wave of personalized medical treatments.

AI's potential in protein design also offers a chance to produce more planet-friendly materials through synthetic biology. Ginkgo Bioworks is one of the leaders in this area and extensively uses machine learning in its "organism engineering" process. This presents an opportunity to develop and mass manufacture new materials to replace today's environmentally intensive extraction of natural materials. For instance, imagine artificial spider silk replacing water- and pesticide-intensive cotton and petrochemical-based fibers. Today, these novel fibers are more expensive than existing ones but achieving cost reductions ought to be a solvable engineering problem, particularly as the new ones have numerous quality advantages.

There is also a perhaps unexpected synthesis between AI as the solution to our deteriorating health and the answer to our unreliable, carbon-intensive energy system. One major challenge for AI is its high computation cost due to its intense energy consumption. INET Oxford's work on the application of Wright's Law to the energy transition suggests renewable energy's long-term cost declines will persist over the coming decades.[16] That provision of increasingly cheap energy (which could be deployed at the site of the supercomputers used to run AI algorithms to avoid grid costs) means it complements the burgeoning AI industry exceptionally well.

Given how effectively AI could assist with many of the limits on the current paradigm, it seems very likely that AI (and AI-based bio-genomics alongside the new biotechnologies) represents the major general-purpose technology of the coming growth wave. This new wave will also see the continuation of renewables-based electrification displacing fossil fuels.[17] Electric vehicles could represent the new transportation mode of this wave—and form part of a package of new consumer goods that also includes personalized medicine and new materials for production processes. In response to geopolitical pressures and pandemic-era realizations about supply-chain frailty, more firms are likely to move from the tripartite structure to a vertically integrated model, with state-owned firms and publicly supported

"national champions" growing their presence.[18] This is the technological backdrop for the three possible scenarios sketched below.

Three Scenarios

Extension of the Fifth Wave. The first scenario assumes that the fifth (ICT plus biotech 1.0) growth wave can actually keep going. Carlota Perez makes this case, arguing that financialization and globalization have extended the older, mass-production paradigm and produced an exceptionally long installation stage for the fifth wave.[19]

Perez argues that each paradigm's synergy period involves the development of a new lifestyle that generates novel demand to help replace jobs lost to productivity improvements. Think about the culture of suburbanization and mass consumption of the fourth paradigm, which government-built highways and the auto industry enabled. Perez believes the seeds of such a lifestyle for our current paradigm are present and can be seen in the lifestyle preferences of the young and more educated in the advanced economies. In her own words, this lifestyle is "centred on health, exercise, caring, creativity, nutritious fresh foods, experiences, learning, communication, rental and maintenance rather than possession and waste. It's already being adopted by the young and the more educated."[20] In this model, "[by using] ICTs, we can turn products into services, possession into sharing, waste into circularity, change our eating habits (to fresh food produced hydroponically around cities) thereby maximising health and reducing environmental damage, make computer guided ships aided by sail and solar, multiply biomaterials and biofuels, and so on."[21]

This scenario's lower material demands and economic circularity would likely mean secularly weak commodity prices (with some exceptions for essential materials) and exert downward pressure on inflation rates, helping governments to attain macroeconomic stability. This scenario resembles Kate Raworth's "donut economics" model, which is broadly "growth-agnostic," focusing instead on wellbeing and generating positive environmental outcomes. That shift in priorities would likely lower overall growth.

There are good reasons to dispute Perez's interpretation though. For a start, the speculative investments Perez decries as an indication that finance is untethered from production could easily indicate that this paradigm is reaching maturity. This would fit the template Perez described in her 2002 book: "their relative success makes firms amass even more money without profitable investment outlets." Perez points to the excessive influence of finance and excessive profits from speculation compared to production as responsible for the unusually long maturity phase of the fourth paradigm and slow installation period of the current growth wave. Perez also argues that globalization, particularly the emergence of China as the "world's factory," extended the mass production paradigm.

These arguments have flaws, however. To begin with, we have evidence that financial sector profitability meaningfully declined after the global financial crisis, with bank return on equity sharply lower over the past decade compared to the 1984 (when the FRED data starts) to 2008 period.[22] That doesn't fit the picture of real economy investment being displaced by money going into speculation. The lower investment rate of the current growth wave seems better explained by the characteristics of the leading firms of the franchise economy, specifically their reliance on intangible capital which requires less investment. Indeed, finance is very much one of the leading industries of the fifth, IP-based paradigm. In a related vein, China's role as the world's factory is not a simple extension of the prior Fordist growth wave. This process was materially different in its disinflationary macroeconomic effects. The corporate organization of Chinese outsourcing and relatively low Chinese domestic demand and consumption suggest the tripartite firm structure more than the high-wage, high-demand Fordist model of the previous paradigm.

Finally, while the "health, exercise, caring, creativity" lifestyles of the young certainly have genuine roots in the usual rejection by youth of prior generations' consumption habits, they also may reflect an adaptation to the economic realities of the franchise economy. Put too simply, many younger Millennials and Gen-Zers just don't have the money to buy resource-intensive objects like automobiles and houses, which in turn induces a delayed transition to adulthood and family formation.[23] So we might conclude that rather than the fourth growth wave being unusually lengthy and the fifth slow to fully establish itself, we have experienced the full cycle of the fifth growth wave. It is simply that, due to the specific features of this paradigm, its macroeconomic consequences have not been favorable to workers in developed markets.

A new paradigm. What about a shift to an entirely new paradigm? As discussed above, AI is a general-purpose technology which helps overcome many of the limits our current growth wave is smashing into, through automation and the design of new medicines and materials. Its Achilles' heel is perhaps its energy-intensive nature, but cheaper renewable energy could ease this constraint. The more activist states emerging in response to domestic socioeconomic discontent and intensifying geo-political competition—especially between the United States and China—have an interest in promoting renewables and latterly AI.

Indeed, American elites' preference for using industrial policy as a tool for countering China may shift the American political economy as it takes effect. The chips Act and Inflation Reduction Act introduced subsidies and incentives for U.S. manufacturing investment related to semiconductors and clean energy, contributing to an American manufacturing investment boom. Notably, "more than 75 percent of all investment [driven by Bidenomics] is headed to Republican-held Congressional districts"—which should create new constituencies supportive of these policies regardless of the outcome of the 2024 election.[24]

Overall, then, this scenario would see the state actively easing the transition into this new growth wave, proactively supporting the emerging leading industries with an expansive industrial policy tool kit. This provides an additional opportunity for the state to push developments in a prosocial direction, building a social consensus around the new growth wave which offers a better deal for workers than the previous franchise-economy model. Given intensifying strategic competition with China and a general uptick in (for now, localized) challenges to U.S. hegemony, it would not be surprising to see the U.S. state repeat its behavior in the Cold War and begin to develop a new social contract to strengthen its internal cohesion to better face potential external conflicts.

This scenario has several notable economic consequences. Growth is straightforward: the features of the new paradigm point to stronger growth based on improved productivity growth, pro-growth fiscal policy, and an aggressive investment cycle. Inflation is a little more complicated. AI and automation seem to represent a sharp advance in labor-displacing and capital-cheapening technology which should push down inflation. Meanwhile, over the long term, synthetic biology and falling renewable energy costs could usher in physical abundance.

Against this, the transition period might be more commodity-intensive in certain areas, and is likely to involve a sharp increase in investment rates and growth—which is likely to be inflationary, especially in an economy conditioned to decades of excess capacity from the franchise economy. Finally, but significantly, a world of trading blocs and "reshoring," where increasing quantities of commodities are synthesized in rich countries, and where labor costs are an increasingly unimportant part of manufacturing costs, will be challenging for much of the Global South.

Incompetence and inflation. Transitions between paradigms frequently involve a period of crisis, which very often is what creates the space for transition away from the politically entrenched older system. That older system has many constituencies with potentially stranded assets that motivate intense

opposition to change. With these realities in mind, this scenario presents a protracted period of crisis over the coming decade, as potential winners from the new technologies battle losers with stranded assets over control of the policies needed to secure the massive investments constitutive of a new paradigm. In this scenario, economic difficulties and volatility characterize the next decade as bottlenecks impede the transition to another growth wave, despite the exhaustion of the fifth paradigm.

A protracted crisis of this kind is historically common. For instance, economists Christopher Freeman and Francisco Louçã identify a crisis between the second and third paradigms in the 1880s and 1890s, which saw a decade-plus period of deflation, growing radicalism in various forms, and sharper geopolitical competition.[25] Freeman and Louçã also identify a severe crisis of adjustment between the third and fourth paradigms, when there was a mismatch between the new Fordist production model and older (more laissez-faire) institutions. This mismatch fueled the boom of the 1920s and the subsequent prolonged depression of the 1930s.

Paraphrasing Mark Twain, this scenario does not simply repeat either previous crisis of adjustment, but it does rhyme. It shares the core similarity of actors attached to the new techno-economic paradigm struggling to instantiate their preferred version of that paradigm in the face of significant long-term physical and social bottlenecks. What might these be?

(1) Commodity shortages could hamper the energy transition. While this problem has become more visible recently, the long lead times inherent to mining projects could mean the issue isn't resolved until the start of the 2030s.

(2) Energy insecurity and volatility pose another bottleneck. Oil supplies appear increasingly geopolitically sensitive and, as the chaos in the Gulf of Aden and the increasingly hot Iran-Israel conflict shows, fragile. Meanwhile, the green energy buildout will also require the construction of new supply chains or be subject to Chinese dominance in key areas.

(3) Related to the above, growing competition between the United States and China might flare up further as each country seeks to secure its supply of commodities and semiconductors while contesting control over Taiwan. If the world partially fractures into distinct trading, financial, and geopolitical spheres it could threaten the steady supply of energy, semiconductors, consumer goods, and certain commodities (including rare earths or perhaps copper given China's central role in processing).

(4) Domestically, policy volatility driven by intensifying political polarization and a concerted pushback by incumbents of the dying growth wave could hamper the leading industries of the coming growth wave. The emergence of new leading industries requires state support and new regulatory frameworks. This applies to green energy and its well-documented partisan battles, but also to other industries such as the new biotechnology, with controversies over the role of stem cell research and in-person gene modification. All of this requires new regulatory frameworks (and underpinning this, a new social contract) that develops to facilitate a more orderly transition. The incumbents of the current growth wave have an incentive to fight the emergence of this new regime by impeding state support or hijacking the regulatory process to support entrenched interests.

A shared undercurrent to the third and fourth bottlenecks is a lack of social consensus about whether to embrace the new growth wave and what this new wave should look like. Instead, incumbents, including potentially displaced workers, hamstring the state's efforts to midwife and shape the transition. Volatile and weak policy may also worsen broader social discomfort with aspects of the emerging growth wave, such as generative AI, due to feelings that the new technologies are controlled entirely by tech giants without any popular input. This could slow the uptake of the new technologies and the ways of doing business that they facilitate.

These factors could mean that new leading industries struggle to emerge, even though the current growth drivers are largely exhausted and moving toward investment levels appropriate for offsetting depreciation rather than generating growth. To be clear, none of this is meant to suggest an apocalyptic scenario. It would, though, be a difficult, volatile, and highly uncertain adjustment period that could stretch into the third decade of this century with a lack of social or elite consensus on where to go next economically.

From a macro perspective, this scenario would mean a painful combination of weaker real growth and poor productivity growth given the constraints on the leading sectors of the coming growth wave. Meanwhile, commodity disruptions and supply bottlenecks would likely mean an inflation rate that is higher and more volatile than that experienced over the past few decades. Finding a successful form of corporate organization would be a major challenge in this environment.

Policy Matters

As we've seen, transitions between growth waves frequently involve prolonged periods of instability due to a mismatch between the new growth engines and production methods and institutions that emerged to serve the prior growth wave. The evidence of the exhaustion of the ICT and biotech 1.0 growth wave, and the challenges to its "franchise" model of corporate organization are clear. That leads us to wonder what new corporate structures and forms of financing will be key to economic coordination in the coming paradigm?

One part of this answer appears to be a return to vertical integration, something we can see clearly in the auto industry. Part of this appears to be driven by the dynamics of the emerging technologies. The new and leading EV manufacturers, Tesla and BYD, are already largely vertically integrated, with both extending integration backward into commodity supply chains. Jim Farley, the CEO of Ford, is also moving his company back toward vertical integration due to the nature of EVs.[26] Similarly, many of the legacy car companies are forming joint ventures to develop batteries for their new vehicles. Volkswagen and Umicore in Europe or Samsung SDI and General Motors in the United States are just two of many examples in this area. In its early days, the auto industry was far less vertically integrated, with a profusion of small-scale specialist firms supplying major parts to larger automakers. Then major assemblers, like GM, vertically integrated and were able to outcompete on cost and quality—producing the industry structure of the Fordist era. A similar process may be playing out here for EVs.

The leading firms of the dying growth wave are also embracing this verticalization, notably in the crucial inputs of semiconductors and energy. The tech giants are increasingly looking at internalizing the design of semiconductors, the core input of the fifth growth wave—Apple's M-series chips and the increase in Apple's R&D-to-sales ratio to design those chips are a high-profile example.[27] But the other tech giants such as Amazon, Alphabet, and Microsoft have all been making similar moves, particularly by constructing new data centers. We see the same phenomenon in energy, driven by the same power-hungry AI we discussed earlier in the piece. The dominant tech firms are investing to secure clean, cheap, and reliable energy. Microsoft's deal with Constellation Energy to revive Three Mile Island was a widely reported example of the broader expansion of corporate power purchase agreements being used by tech firms to secure their energy supplies by effectively underwriting the development and/or operation of specific projects.

It makes sense that firms facing a more uncertain world with insecurity around the supply of key inputs would attempt to vertically integrate. Research findings confirm the intuitive notion that vertical integration raised corporate returns for firms following the initial Covid shock by insulating them from disruption.[28] Indeed, we can quite clearly see the tech giants either directly or indirectly looking to internalize more of their supply chains following the Covid and Ukraine war disruptions to the critical

inputs to production of energy and semiconductors. This could very well suggest that the companies earning an outsized share of profits in the coming decades will have to invest more to maintain their standing than they did in the franchise era.

We are also witnessing the growth in importance of sovereign wealth funds (SWFs) and state investment for corporate financing, which is partly being driven by states pushing to internalize more strategic economic activity. Milan Babić has written extensively on the growing role and variegated forms of state capital in global finance, but stresses acquisitions by state-owned firms trying to obtain strategic assets and technologies. The remarkable explosion of industrial policy, especially in America, is by now well-known to readers of this journal. So, we'll simply point out that this is providing another alternative form of financing to corporations when their activities align with the strategic vision of the state.

Those strategic visions emerge from real conflicts over the distribution of power, control, and money in the global economy. Even the post–Cold War 1990s saw market-versus-state geopolitical contests, with competition between the self-described market-driven American and state-led East Asian economic models. Now the contest is between two different flavors of state. The first is money-printer-style industrial policy in the United States; the second is Chinese state capitalism. The countries with states who can't or won't try either approach end up with pathetic long-term growth, exemplified by Britain, Italy, and Germany.

All these considerations about new corporate forms and state financing pale before the macroeconomic factor that Perez adds to Schumpeter's make, move, and market model. Rising income inequality has driven a wedge between potential supply and actual demand almost everywhere, as well as igniting destabilizing political movements. A world like that in H. G. Wells's Time Machine, with asset-owning Eloi employing personal yoga trainers while gig-working Morlocks see rent absorbing half their income, is neither economically robust nor politically sustainable. Demographic trends might generate tighter labor markets and thus reduce economic divisions, but AI-enhanced automation will push back against that. Put simply, new technologies and thus new growth do not install themselves. This is the moment at which policy matters above almost all other considerations.

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