WORLD ECONOMIC FORUM

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White Paper

Shaping the Future of Production: Four Contrasting Perspectives in 2030

In collaboration with A.T. Kearney

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Contents

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Preface

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This World Economic Forum white paper is proposed in the context of the Forum's System Initiative on Shaping the Future of Production, launched in 2016, which seeks to better understand transformations in global and local production systems and to provide a platform for pilots and collaborative efforts that stimulate innovation, sustainability and employment.

The Forum defines the world of production as the full chain of activities to "source-make-deliver-consume-reintegrate products and services", from origination, product design, manufacturing and distribution to customers and consumers, incorporating principles of the circular economy and reuse.

Production fundamentally impacts economic structure at global, regional, national and local levels, affecting the level and nature of employment, and today is inextricable from environmental and sustainability concerns, considerations and initiatives. Collectively, the sectors of production have been the source of economic growth in developed and developing nations alike, a major source of employment for a rapidly evolving and increasingly skilled workforce, and they continue to be the dominant focus of innovation and development efforts in most countries.

The transformative potential of technology in production systems is widely recognized, even while the precise configuration and extent of the possible transformation remain unknown. Trends towards higher levels of automation promise greater speed and precision of production as well as reduced exposure to dangerous tasks for employees. New production technologies could help overcome the stagnant productivity of recent decades and make way for more value-added activity. The extent of automation is, however, causing significant anxiety about issues of employment and inequality.

The new technologies of the Fourth Industrial Revolution have the potential to transform the global geography of production and will need to be deployed in ways that address and adapt to the impact of climate change.

This white paper, prepared in collaboration with A.T. Kearney, explores the new technology landscape focusing on five technologies that will have the most immediate impact on production-related sectors, individually and in combination. It raises questions for chief executive officers, government leaders, civil society leaders and academics about the implications for individuals, companies, industries, economies and society as a whole, and is intended to bring new perspectives and generate responsive and responsible choices.

Introduction: Visions of production in 2030

As part of an ambitious effort to assess and shape future global systems, the World Economic Forum has mobilized a number of distinguished individuals from around the world – representing government, civil society, academia and the private sector – to examine the Future of Production. This is a subject at the centre of the sweeping transformation characterized by World Economic Forum Founder and Executive Chairman Klaus Schwab as the Fourth Industrial Revolution, which will influence the fundamental ways in which we "live, work, and relate to one another"1 in the future. By definition, it affects our level of economic prosperity and economic development, our stewardship of the physical environment, the degree to which our societies are inclusive, and the mix of opportunities and challenges in the external environment within which we produce.

The trajectory of production, especially up to the year 2030, is profoundly uncertain. At the core of this uncertainty are questions relating to advances in a number of technologies that are central to shifts in production, including analytics and artificial intelligence (AI), the internet of things (IoT), robotics and automation, wearable devices and additive manufacturing (3D printing). How these and other technologies will evolve, the rate at which they will be incorporated into production processes and the sequence through which they will assume greater prominence in production are all unknown.

Superimposed on the uncertainties relating to core production technologies are equally profound questions about the shape of the external (or contextual) environment within which the future of production will unfold. Recent elections and political developments in both developed and developing countries may be examples of a potential popular backlash to the system of globalization that has dominated the world's economy over recent decades.

The multilateral world in which we now live – characterized by global competition, not only from traditional superpowers, but also from new global powers – raises significant new questions with respect to stability and security. Several regional tensions have resurfaced. Beyond that, wholesale new layers of instability – most notably, the emergence of globalized terrorist movements – have changed the landscape.

In addition, significant doubts have emerged about how the global economy will develop over the next 14 years and beyond. In its most recent *World Economic Outlook*, the International Monetary Fund asserted that "the need for a broad-based policy response to raise growth and manage vulnerabilities [is] more urgent than ever".[2] With the spectre of heightened trade tensions and continued pre-2008 levels of global cross-border flows, new and compelling questions have arisen about the future path of globalization. In advanced economies in particular, basic uncertainties relating to flat or negative factor productivity growth cloud the future outlook.

Finally, institutions are under pressure as never before. No matter what the class of social organization – government, business, non-governmental organization (NGO), academic institution, religious group or other – there is considerable evidence to suggest that the current highly complex environment implies challenges that are beyond the capacity of most institutions to address effectively.

Within this complex and volatile external environment, the differing trajectories in production will play themselves out. In the process, they will affect innovation, sustainability and employment in societies across the planet.

The goal of the multi-year Future of Production initiative is to abate some of these tensions by developing a common vision on how societies can shape future production in such a way that it reinforces prosperity, opportunity, environmental sustainability and social progress that is inclusive and broad-based. To that end, the initiative will generate three initial outputs that reflect the deliberations, conclusions and recommendations of the global network of experts, policy-makers and corporates associated with the effort.

This white paper addresses one of those three initial outputs. The four scenarios proposed here: Disrupted, Deterred, Damaged and Devolved (see Appendix for a summary of the scenario elements) focus on exploring the contrasting visions of the future of production up to the year 2030 (Figure 1). This exercise does not seek to advocate or opine on the likelihood or realism of any given scenario, but simply uses the tried and tested approach of scenario-based strategic planning to prepare for multiple and plausible futures, in such a way that organizations can be ready to act effectively.

What is the goal of developing and disseminating these scenarios? Since stakeholders in the Forum's Future of Production initiative represent diverse organizations and interests, we seek to explore general sets of conditions that enable the full spectrum of participants to anticipate and plan for the future.

1. Klaus Schwab, The Fourth Industrial Revolution (Geneva: World Economic Forum: 2016), p. 1.
2. World Economic Outlook, October 2016: Subdued Demand: Symptoms and Remedies, International Monetary Fund.

Figure 1: Summary of drivers and scenarios

Six drivers combine to create **four distinct scenarios** for how production will play out through to 2030.

The objective is to make the scenarios, which are narratives on the future, sufficiently general to apply to all groups, while specific enough to help organizations put their own perspectives and priorities into a broader context (Table 1).

This white paper incorporates opinions gathered from over 400 participants across all stakeholder types and geographies at World Economic Forum regional meetings in Latin America, ASEAN and Africa and refined at the Annual Meeting of New Champions 2016 and during the Global Future Council and International Business Council meetings. It reflects global, regional and local perspectives to refine the main drivers and explore a range of opinions and possible outcomes.

The scenarios were developed in partnership with A.T. Kearney.

The Global Future Council, Steering Committee and many global experts and Partner company executives (see Acknowledgments) helped us to think through the key uncertainties and implications of the scenarios for different regions and stakeholders, providing feedback and expertise for which we are extremely grateful.

Table 1 provides context on the use of scenarios.

Table 1: Context on the use of scenarios

What scenarios are…	…and what scenarios are not
Scenarios are compelling, plausible narratives on potential outcomes, to help leaders anticipate and plan for the future.	Scenarios are not predictions of the future. Nor do they generate futures to which we should assign probabilities.
Scenarios focus on potential change in the external environment that can reshape the strategic environment.	Scenarios do not focus on specific operational options that can be pursued by individual organizations.
Scenarios inform the formulation and implementation of strategy.	Scenarios are not strategies in themselves, but do provide insight for planning.
In an age of big data, scenarios help us to foresee potential outcomes that are beyond the numbers.	Scenarios are not the same as trend analysis, empirical forecasting or other foresight methodologies.

Disrupted: Production transformed

We all expected the take-off of a number of exponential technologies, but no one anticipated the amazing changes that came with early breakthroughs – especially in deep learning – which propelled artificial and machine intelligence to unimaginable levels. There can be absolutely no doubt that in 2030 we have arrived, ready or not, at the Fourth Industrial Revolution and the full range of the opportunities and challenges it implies. The hyperconvergence of key technologies is no longer just "near". It is happening. And for better and for worse, this is shaping our world in the most fundamental ways.

Fifteen years ago, artificial intelligence (AI) started an unexpectedly rapid shift from theory to practice. By the early 2020s, it had dramatically transformed production, as well as redefined a number of other critical elements in our lives.

Multiple technological advances created nothing less than a contemporary renaissance. By itself, each of these advances would have had a remarkable impact. When taken together, they brought about a convergence that would reshape our world.

The progress was fuelled by an unprecedented wave of venture capital investment that began in the 2010s. Many had foreseen a boom and bust cycle in the initial capital directed to AI-related ventures, but they were dead wrong. Innovation exploded in AI and in other related areas. The apposition of continued rapid advances in supercomputation and increasingly sophisticated analytics sealed the deal. The demarcation line was passed when existing AI capabilities transcended the early image and voice recognition achievements, opening up the space for a far wider range of cognitive technologies that could "learn." The rest, as they say, is history.

Throughout the world, those changes would run the gamut, affecting how, how well, where, and even why we live our lives. They would fundamentally redefine the point of departure for the post-Z generation – children born after 2015 – as well as the Zs, the Millennials and the remaining Boomers.

AI moved to the epicentre of production in the space of a mere decade, from 2020 to 2030. For starters, deep-learning machines achieved one breakthrough after another, when at long last they succeeded in "understanding" the unimaginable amounts of big data that had been collected. Forget about narrow AI, when machines managed to one-up humans in specific tasks (such as clearly defined factory floor tasks) or even games (such as chess or Go). Much faster than predicted, machines moved into the general AI sphere, in which they integrated complex and diverse inputs on the scale of humans, often performing far better. Their march towards authentic AI – the "super-intelligence" level – came much earlier than the expert timelines had suggested.

Initially, the new "digital brains" – centres of super intelligence – that emerged were concentrated in Silicon Valley. At the time, they were dominated by the big search engines and social network providers doing the cutting-edge work in AI. Soon, however, they spread to other industries and geographies, often with the aggressive support of government research and development (R&D) and subsidy programmes. In the 2020s, it soon became clear that the new rivalry between major powers, which had been expressed in economic competition, had moved well beyond that, into supercomputing and the AI sphere.

In the space of a decade, from 2020 to 2030, AI moved to the epicentre of the production calculus. For starters, deep-learning machines achieved one breakthrough after another, when at long last they succeeded in "understanding" and processing unimaginable amounts of data.

Internet of things (IoT) devices have continued to mushroom, with ubiquitous and connected sensors deployed from factory floors to equipment, the home and even within humans. The number of "machines" linked through IoT has now reached some 300 billion. Combined with further advances in big data and analytics, powerful capabilities have enhanced decision-making, empowered customer engagement, optimized resource management and enabled planning based on powerful predictive and prescriptive analytics and ever more sophisticated algorithms. There have been corresponding advances in robotics and 3D printing. Across virtually all industries, robotics has gained ever greater traction. And the complete transition of 3D printing from prototype-only use to wide-spectrum application has transformed the entire production landscape.

Together, these diverse and profound technology innovations have disrupted traditional economic dynamics and the production process. It all amounts to a massive technology-induced redefinition of the value chain. It is a "same planet, different world" proposition.

Around the world, economic activity has taken off. Average annual growth of this technology renaissance has led to a revival of globalization, which had stalled in the 2010s after the emergence of nationalism and protectionism in some of the major economies – the byproduct of the so-called politics of rage. Since then, the new suite of technological capabilities has translated into higher levels of productivity, efficiency, resource management and stewardship, and new opportunities for consumers. Overall, the expectation of a long boom of economic growth was reflected across economies and secondary markets.

Furthermore, in the same style of the early "disruptors" in the 2010s, new companies have succeeded in wringing out any remaining inefficiencies in manufacturing systems and product processes, service-sector offerings and decision-making processes. A number of developing countries have leveraged the new technologies to gain leapfrog effects for their economies. While many of the economies remain detached from the innovation process driving large numbers of these changes, the rapid diffusion of opportunities opens up a number of important options for rapid and sustained national development. However, overall, the application of new production technologies in developing countries is uneven. Some economies simply do not have the physical infrastructure and workforce to fully leverage the ongoing paradigm shift in production.

> Together these diverse and profound technology innovations have disrupted – in the fullest sense of the long overused word – traditional economic dynamics and the production process.

Poverty levels continue to decline, in line with the United Nations' 2030 targets. Income and wealth disparities between and within countries persist, especially in the economies where technological advances are taking place, but with pervasive economic growth and opportunity, the gap is gradually closing. Still, all concerned acknowledge that continued progress needs to be made in order to make the sweeping technological changes as inclusive as possible.

The ability of government, business, civil society and other leaders to pursue higher levels of sustainability increases with these technologies. Although the ideal of a circular economy has yet to be fully realized, tremendous gains have been made in reducing degradation of the physical environment, preserving biodiversity, conserving resources (especially freshwater) and addressing land degradation. Global warming continues to represent an acute concern, but governments are succeeding in reducing emissions and driving up efficiencies. International cooperation in achieving these goals is gaining momentum. Even so, the heavy human costs associated with ongoing environmental damage are increasing unabated.

Much of this progress is the result of far-sighted policies adopted by governments. The challenge to policy-makers was threefold:

- First, it fell on the public sector in several economies to encourage development of technologies and transformation of the production process through the mobilization of strategic investments, the development of an enabling tax, regulatory environment and physical infrastructure conducive to growth, and the creation of visionary public–private sector partnerships.
- Second, governments exploited their positions as customers with the capacity to enable a production base. Building on the early century models of Silicon Valley and the US Defense Advanced Research Projects Agency (DARPA), they provided direct support in those areas with high barriers to entry.
- Third, several governments assigned a high priority to addressing the challenge of dislocated workers. A number of imaginative programmes were set in place to upskill/ reskill affected worker segments, as well as to aggressively identify new job opportunities. Partnerships were created with trade unions, NGOs, academic groups and others, to cushion the significant effects of this economic transformation. While the change still resulted in a stranded class of workers, the aggregate impact has been significantly lower than it would have been otherwise. "This really was a good faith effort to deal with the big downside of these forces", a labour union leader observed. "Still, we need to ensure that in the end, things don't translate into jobless reshoring".

Our "factories" today would be unrecognizable from those of just 15 years ago. Virtual ecosystems, propelled by human-machine collaboration, marked by real-time communication and integration on the floor, linked with external environments simultaneously, and characterized by location-agnostic operations based solely on the source of demand, have replaced the non-automated, wasteful and inefficient models of the past. It is a totally new production paradigm, plain and simple.

The basis of governance of production has changed considerably. Beyond upskilling/reskilling programmes, today's workers differ from those of the past. The most significant contrast is the onset of wearables earlier in the century, which set the stage for the current technology-augmented human. New, augmented virtual reality training programmes enable workers to come up to speed extremely rapidly. Sensors provide real-time information on location, productivity, safety and a range of additional critical performance metrics. All in all, these tools serve to enhance capabilities in ways that are simply unprecedented.

Still, even those workers thriving in the economic dynamism are concerned about an economy in which they are being left behind by machines that are ever smarter and more capable. "The AI strides of the past few years are astonishing", one worker observed. "It seems like we're on countdown for the new convergence – the point at which we can't tell the difference between tech-augmented humans and AI-augmented machines".

In addition, there continues to be serious concern about the nature and quality of the jobs left for humans. It all depends on how close you are to technology's cutting edge, many analysts have observed. History has shown that the gains for those defining the new convergence of technologies can generate extraordinary returns. Those left behind must find ways to navigate in an alien and unrelenting world. It is a workforce pulled by the extremes, from a formal sector benefiting greatly from the convergence on the one hand, and an informal sector seeking to persevere in a hyperdynamic environment on the other.

It is the end of mass anything. Thanks to ubiquitous digital technologies, the lion's share of production is fully customized and delivered in real time. As a result, the marketplace is characterized by digital "selfies" on virtually any product for sale – houses, cars, transportation, entertainment, education, personalized medicine, and so on. In this production environment, the drivers of value shift to R&D, sales and marketing, and access to data. "This is the embodiment of what former US Federal Reserve Chairman Alan Greenspan identified decades ago: a "weightless" economy driven not by commodities, but rather by ones and zeros", wrote one economics professor.

Deterred: Production undercut

A crippling cyberattack that simultaneously compromised large segments of critical infrastructure and interrupted production processes in the early 2020s was a clear indication of how vulnerable systems around the world had become. What was not anticipated was that production would be caught in the crossfire of a pervasive cyber conflict between states and their proxies.

It all seemed too good to be true. Massive supercomputers and AI mobilized in support of addressing global challenges and improving the human condition. Exotic new digital and bio-technologies aimed to reach new breakthroughs in treating human disease, ramping up environmental stewardship and generating new levels of inclusive prosperity. Pervasive sensors helped us to improve the quality of our lives, the interactions we have with one another, the effectiveness of our institutions and the ways in which we produce. The remarkable upsides notwithstanding, it should have been clear a long time ago that the downsides were much greater. The heavy price was loss of security, erosion of privacy, concern over stability, production grinding to a near standstill and agonizing decisions on how to try to defend against the new and changing cyber-based threats of the year 2030.

It was the space race all over again. This time, however, it was between not two, but several countries, all of which recognized the growing power – military, political, economic and commercial – associated with the unfolding digital revolution. The rationale for developing offensive information warfare capabilities was compelling: countries needed to stay ahead of the AI race to avoid being consumed by it.

There certainly were a number of high-profile incidents years ago to indicate where things might go. Denial-of-Services (DoS) and other cyberattacks on major private corporations were so common in the 2010s that they stopped being top-of-screen news items. Hackers employed tens of millions of unprotected IoT devices to conduct another DoS attack on major internet service providers. Spectacularly, this highlighted the dangers associated with pervasive bare- metal coding – the low level of coding ubiquitous in past generation hardware and subject to easy hacking – and the high costs associated with retrofitting wholesale systems to reduce or remove vulnerabilities.

It all began when hackers unleashed an unwitting army of compromised internet-connected devices (including security cameras, digital video records, home internet routers and even baby monitors) against their target of choice. Many of these devices were open invitations to hackers because they had “hard-coded” (non-manipulability by user) passwords and system back doors.

While the effects of these early cyberattacks were obvious, the sources were considerably more difficult to pinpoint.

Time and time again, it was nigh impossible to detect the source of the attack, due to sophisticated evasion techniques. It was harder still to pursue any kind of legal action (or other counter strategy) in the face of the pervasive uncertainty.

In this high-stakes environment, it was only a matter of time before nation-states themselves engaged in cyber actions as part of their overall strategies. As AI continued to develop, they were on countdown to exploit the extraordinary new capabilities that it represented. Sometime in the early 2020s they unleashed a number of AI “hackers” – intelligent software designed to carry out discreet missions with the capacity to analyse millions of programmes looking for vulnerabilities – that would ultimately have a devastating impact by crippling parts of the critical infrastructure and, in the process, undercutting potential gains in production.

> How will production evolve in an environment marked by serious technology-expressed disruption, competition and conflict in cyberspace?

These new classes of weapons targeted a range of vital elements, including networks governing communication, transportation, physical infrastructure, energy and utilities, financial systems, government operations and the private sector. It was subversion, warfare and espionage by another highly sophisticated and independent channel of delivery: AI. The onset of AI hacking led to a new phase of counter-operations designed to defend against the emerging class of threat. The internet became the unwilling host to major cat-and-mouse operations.

For their part, non-state actors, starting with international terrorist groups, perpetuated the use of information technologies and social networks to spread propaganda, recruit members and communicate with one another.

Advances in AI also gave them the ability to mount attacks. Other private groups, including criminal enterprises, also looked to leverage newly developed positions in AI and other digital technologies. Scamming over the internet was no longer sufficient. They soon expanded operations by building on their past track record of ransomware and illegal gambling. “Any single day could turn out to be an existential test for our cyber structure”, a prominent chief executive of a global corporation observed.

Another significant by-product of these developments was the start–stop effect they had on the development of production. With each revelation of attack, new technologies and techniques became necessary to "harden" the process,

so that it was less vulnerable to future assault or interruption. As a result, the ongoing cyber tension served as a significant drag on restored economic growth. Economists believe that for the past seven years, it has accounted for the equivalent of 1.5% in foregone annual global output growth. This has translated into the indefinite perpetuation of the flat economic conditions that had started in the aftermath of the Great Recession, adding to high levels of public dissatisfaction with government and its capacity to protect the economy and promote growth and opportunity. The less-than-optimal circumstances resulted in greater degrees of economic stratification between and within states. To increasing degrees, governments have pursued predatory policies in trade in goods and services, investment, intellectual property protection and technology advances.

While developed economies with greater concentrations of technology and wealth were the main targets of this nefarious activity, the reverberations soon spread to developing economies. These were especially vulnerable because they had fewer of the defences to attacks than existed elsewhere. In various important ways, they have been caught in the crossfire.

> The heavy price was loss of security, erosion of privacy, concern over stability and agonizing decisions on how to try to defend against the new and changing cyber-based threats of the year 2030.

The cyber Cold War that ensued means that the capacity of the international community to address the big global issues

dealing with climate change, reducing poverty, restoring economic growth and confronting international crime, among others – has been considerably diminished. All in all, after a three-year ramp-up period, the cyber war has been in full force for the past 10 years, a period now referred to as "the lost decade of growth and prosperity". No one knows how many cyber-improvised explosive devices (IEDs) will interrupt opportunities in the future.

The chain of events threw the spotlight on the differing roles of government in addressing the issue of technology instability. The key focus was the question of if and, if so, how governments should seek to "manage" adaptation of technology, especially in sectors considered to be strategic. In most cases, as the level of attacks escalated and governments pursued highly defensive policies designed to limit their exposure to cyber-based vulnerabilities. National programmes focused mainly on two areas of policy. The first was to generate and regulate national software policies, which were designed not only to compartmentalize economies from malicious code, but also to establish standards that might extend to other regions and countries. The second was the fusing of national research facilities with the time-tested notion of national economic zones. This hybrid notion allowed for the development of new technologies, as well as for greater protection of new processes from the long reach of AI hackers.

The results, leading up to where we are now, are islands of innovation that are segmented, proprietary and heavily protected. The pace of automation and robotics has slowed due to concern about the introduction of hardware or code that will compromise the integrity of the operation. The same observation applies to the implementation of other new technologies.

Nevertheless, the model by which corporations now operate has fundamentally changed over the past decade. As scientific discovery and technological innovation have both progressed, business models have not only become far less labour intensive, but also less capital intensive. The new and highly segmented (and protected) "semi-sharing" economy has developed from its origins in cars and hotels, and now operates in many industries where spare parts, capacity and even power are shared. Aircraft engines are shared between planes as needed to maximize utilization. Unused stored power is shared between neighbouring buildings and unused factory capacity is quickly and automatically retooled for lease to another user. The resultant business model is low-asset ownership, with value being created and stored in intellectual property. The assets are owned by a small number of large players who specialize in generating the greatest efficiencies and advancing the technology, while the major technology owners use AI and virtual reality to design new products and experiences, and engage customers ever more deeply.

The lion's share of the limited benefits of technological advances has gone to investors and management. The economic paradigm, such as it is, has failed to create new opportunities for displaced workers. More and more people are chasing a diminishing number of high-worth knowledge jobs, and the gaps between the wealthy and the poor have grown. Embattled governments around the world have sought ways to respond. Various approaches have been tried. In some economies, a lack of action has already begun to spark civil disruptions. Several countries have introduced taxes on machines. Others have attempted to raise corporate tax rates and implement more progressive tax systems to redistribute wealth. Still others are experimenting with a "universal basic income" in an effort to break the historic link between work and wages. However, it is a race against time. Civil unrest is growing, with masses of unemployed workers struggling to adapt to new realities and new ways of life.

> It is hard not to imagine how much progress might have occurred in the absence of the cyber conflict that has overshadowed us all.

Most production platforms undergo careful scrutiny with respect to their "technology overhang". The goal is to determine whether they might be compromised by the new AI hackers or other cyber weapons. This implies retrofitting some existing systems, especially in critical infrastructure sectors.

For workers, understandably, the results of this impaired economic outlook have been extremely difficult to accommodate. Both unemployment and underemployment have increased significantly, and there has been a discernible shift from a formal to an informal economy. In the meantime, especially in manufacturing, the substitution of machine for human has continued relentlessly. The issue has assumed a high profile in political discussion, as battered segments of workers seek ways to rebuild their positions.

Some leaders have pushed for a return to labour-intensive industries, but public support notwithstanding, this has met with limited success. The highly automated environment that had emerged prior to the onset of the cyber conflict, even the part most seriously jeopardized by the AI hacker threat, was still a significant force in production. Withering economies, in effect, continued to produce on borrowed time.

Even so, small and medium-sized enterprises have managed to thrive, filling the gaps left by economy-of-scale producers unable to convert their technology endowments. By contrast, in areas of promising segmented technologies, national "super majors" have emerged with the capacity to vertically integrate themselves to leverage new innovations. The big winners are monitoring and verification products designed to "certify" existing stocks of technologies.

Consumption patterns are a sign of the times, reflecting heightened public concern over the impact of tainted technology that could affect their homes and families. The technology craze that drove markets earlier in the century was replaced by a "keep it simple" campaign, which extended from shopping lists to purchases of durables.

Although digital natives, especially Millennials, struggled to shake their addictions to screens, there was a conspicuous return to physical stores, non-digital purchases and a "simple" and "tiny" lifestyle.

Damaged: Production stratified

Rampant populism and unbridled protectionism translate into a profoundly uneven landscape for global production. Changes in the nature of production up to the year 2030 are limited as a result of ever onerous constraints that come with competing national positions. It is the widespread "islandization" of both economies and the production systems that undergird them, and the spectre of a new worldwide economic depression.

More than 15 years have now passed since the revolt against the economic order and mistrust against the experts who ran it took deep root in several major economies across the planet. Globalization – perceived as a key driver of growth, economic prosperity and social progress at the outset of the century – is now widely reviled in many of the same countries that had once been its greatest champions. Analysts point to the 2016–2026 period as the "lost decade", due to the renunciation of economic multilateralism and a rejection of the notion of comparative advantage. The past 15 years represent a period of positions and policies that have been unabashedly in support of de-globalization.

Years of low growth and productivity have taken their toll, displacing workers, heightening public anxiety about the future, highlighting the inability of governments to help their populations adapt, and fanning nationalist sentiment. Above all, stalled growth has served to legitimize the rise of extremists, who have exploited rising public anxiety about the continued effects of globalization and technological innovation.

> Production is stratified between those economies seeking to leverage new technologies and others that do not have production-of-scale or first-mover advantage.

It all followed a consistent pattern. An embattled public became increasingly dissatisfied with its leadership, political rancour and polarization have made governance structures even less viable, and leaders retreated to simple solutions and old, familiar territory, trying to create control within individual borders in the face of rapid and disruptive change. Especially in democratic systems subject to significant shifts in voter trust, the political yo-yoing has massive implications for continuity of government and policies, to say nothing of international frameworks. As a visionary analyst put it in 2014, we have arrived at "the end of power" as we have known it.

Several countries, many of them with powerful economies, have responded with escalating and retaliatory beggar-thy-neighbour protectionist policies. Due to the imposition of new and more onerous tariff and non-tariff barriers, international trading systems and regional trade structures have all come under unprecedented pressure. Other countries have been unable to make decisions as a result of acute polarization in their governance structures.

As a consequence, economic statism – a hyper-*dirigisme* – is rapidly on the rise. Practices that were abandoned in most economies with the emergence of globalization at the end of the 20th century – governments picking national champions, laying down industrial policies, holding controlling shares in major companies, controlling basic research and R&D, and allocating resources on the basis of political priorities – are returning with a vengeance.

The results are all too predictable. They include cross-border flows of goods and services, portfolio and direct capital, and workers have contracted to levels well below where they were two decades ago prior to the Great Recession in 2008. In addition, average constant global output growth in the 2020–2030 interval was a mere 2.6%, compared with the corresponding level of 3.7% from 2010 to 2020. This globalization whiplash has occurred in spite of repeated warnings about what happened almost exactly 100 years earlier. The current circumstances are fundamentally different, leaders assert. But the parallels to the Great Depression remain strikingly similar.

It starts with the large and unsustainable debt overhangs carried by the bigger economies. Two decades earlier, central banks had mobilized the most aggressive monetary expansion in history, in response to the Great Recession. Not only did they fail to jump-start sustained economic growth, but they also depleted many of the traditional monetary instruments formerly at their disposal. The stock of global public and private debt, which stood at over $150 trillion in 2016, more than twice the size of the global economy at that time, has ballooned to almost three times the size of current global output. One central bank governor wondered "how long can we fight a major monetary war without any significant real-time ammunition?"

In addition, protracted low or even negative levels of growth have translated into lower government tax receipts, which in turn have added to unprecedented pressures on fiscal policy. For many economies, a parallel old-age overhang means even less by way of manœuvrability when it comes to discretionary versus mandatory public expenditures. As a result, they have fewer resources to subsidize their national champions and greater pressure to address higher levels of unemployment.

The momentum built earlier in the century for international environmental cooperation, the outgrowth of the COP 21 framework and unexpectedly rapid implementation by the major signatories is waning. Efforts to address climate change and other key dimensions of environmental degradation are subordinated to more immediate economic priorities, those

of promoting renewed growth and generating jobs. "Worrying about the weather is only possible after I've put food on the table for my children", lamented one worker. The ironic upside is that depressed economic growth leads to less in the way of environmental degradation. Investment flows decline to a trickle. Currency and other restrictions on cross-border transactions have sucked the oxygen out of the international trading system.

All in all, the circumstances are eerily reminiscent of those present in 1933, when former US President Calvin Coolidge observed "in other periods of depression, it has always been possible to see some things which were solid and upon which you could base hope…but as I look about, I now see nothing to give ground to hope".

Cushioned by the highly adverse economic conditions, the widely anticipated effect of labour dislocation is far more gradual than expected. Still, the issue is charged politically.

The impact on production has been highly destructive and uneven. Production is stratified between those economies seeking to leverage new technologies and others that do not have production-of-scale or first-mover advantage.

It comes as little surprise that the largest economies with the capacity to translate scientific discovery into technological innovation maintain their dominant position in the limited global production environment. Another critical variable underpinning their position in production is the capacity to mobilize appropriate resources, especially capital, to modernize the overall process. Lower energy prices that are the outgrowth of falling global demand tilt the process to energy-intensive alternatives. Still, production rates pale in comparison with levels that existed prior to the trade tensions.

By contrast, economies with low labour costs and marginal productivity levels are hardest hit. The decline of the global trading system, coupled with the drumbeat of labour-displacing technologies, means that producers are no longer as compelled to exploit cross-border labour differentials.

Especially in the current political environment, the risks associated with global operations grow considerably. For many developing markets, the de-globalization phenomenon has come to signify an acute deceleration in growth and prosperity.

Companies, especially multinationals targeted by protectionist groups objecting to their international exposure, move away from the sophisticated global supply chain strategies that governed their operations earlier in the century. To an increasing degree, "localization inside a global footprint" becomes the operating norm for large companies facing growing public distrust and protectionism. One prominent chief executive remembered how, at a point much earlier in his career, globalization, productivity and innovation were the dominant organizing concepts. "Now", he comments, "all three are reviled".

As global supply chains are disassembled or reduced, prior gains in procurement and process costs made possible by digitalization simply no longer apply. As one chief product offier noted, "All the digitalization we baked into global operation – big data, analytics and so on – has gone by the wayside in the current and uncertain political context".

Protracted low levels of growth have translated into lower government tax receipts, which in turn have added to unprecedented pressures on fiscal policy. For many economies, a parallel old-age overhang means even less by way of manœuvrability when it comes to discretionary versus mandatory.

In this environment, factory floors in the production epicentres continue to move slowly in the direction of automation, with little or no growth in the number and sophistication of machines. It begins with the connection of wireless devices, including hitherto unconnected devices, to one another. In parallel, the proliferation of sensors and other miniaturized elements with connectivity brings new dimensions to the production process. As a result, most facilities develop the capacity of sensing most key aspects of the production environment.

The widely anticipated effect of labour dislocation through automation is more gradual than under normal globalization circumstances. Still, the issue is as politically charged as the allegations of off-shoring three decades ago, or those of downsizing that surfaced in the 1990s. Companies and governments are on the defensive when it comes to addressing the growing challenges of national workers who have lost their jobs.

In its place, governments opt for a reshoring of migrant workers. Nationalist sentiment swells to the point at which authorities actively identify illegal workers and return them to their countries. The process then expands to permitted foreign workers, except for those in countries with which reciprocal agreements on labour exist. The rationale for these deportations, expressed bluntly in many capitals, is that foreigners are "stealing" jobs that should be filled by national workers. Contrary to expectations, however, many of the segments opened by the deportations, especially those involving hard labour, are not filled by nationals, and the resulting dislocations drive up labour costs and prompt wage inflation.

Corporations follow the growth by shifting their focus and localizing their operations in those countries most willing to provide conditions conducive to higher returns on investment. This includes countries willing to commit fiscal resources to modernizing and expanding physical infrastructure, those ready to promulgate and enforce a transparent and competitive corporate tax code, and those committed to providing an educated workforce and to supporting basic R&D.

For their part, workers also feel the pinch. "We see a lot of the benefits that new technologies are having on production, but the domestic prices have climbed so high that we simply can't afford to buy them", says one.

Globally, the stratification in production between and within economies widens profoundly. The corresponding gap in income levels leads to new tensions between developed and developing economies, and within countries in both stages of development.

It all amounts to "islandization" – the antithesis of globalization of both economies and the production systems that undergird them. While the economic costs have already been onerous, the prospects are even more daunting.

Devolved: Production redirected

Citizens the world over have had enough. A sharp deterioration in the physical environment around them is more than obvious. Equally clear is the fact that humanity is doing far too little to address the enormity or the urgency of the threat. Or to mitigate its consequences, which are becoming more devastating by the day.

Each year, the effects of climate change have become more severe. As the early predictions suggested, we now stand at a point about 2°C above where we were 15 years ago.

Tragically, the list of submerged vulnerable island states is now substantially shorter, and the number of global warming refugees correspondingly larger. We estimate that about 125 million people, many of whom were small-scale farmers, have been driven into poverty.

Around the world, extreme weather events are changing lives. Natural disasters have become the status quo, the not-so-new normal. Persistently higher temperatures and severe conditions are reshaping the agricultural landscape.

The all-too-predictable result is the recurrence of the historical droughts that have occurred repeatedly in selected regions of the planet. While tackling food security was important in the past, it is now critical in order to avoid the famine and other catastrophes that dwarf the disasters of 15 years ago. Large populations are at serious risk. And developing countries, as one might expect, have fewer resources with which to address the challenges.

Call it too little, too late, but in the early 2020s, governments began to assume more responsibility for responding to the worsening circumstances. As one grudging politician reluctantly admitted, “Business as usual is simply no longer an option. We really have to face down this reality, whether we like it or not”.

Worldwide, governments in advanced and developing economies alike have engaged in crash programmes to reduce their emissions footprints and to implement policies aimed at mitigation. A massive shift, as fossil fuels may have finally peaked, is now underway to set in place infrastructures that bring renewable energy to the fore. Battery-powered vehicles have been on the rise and significant shifts have already occurred in many electricity markets. Reliance on solar, wind and other renewables is being built into new grids under construction. The key policy decisions now under consideration will dictate who are the winners and losers for years to come, as strategies are finalized and investment choices are made regarding smart roads, energy grids, battery storage resources, electric vehicle power and other areas that will ultimately shape energy independence and competitiveness as well as emissions levels.

At long last, a pattern of cooperation that involves private initiatives is developing. Coalitions across companies and NGOs to develop cleaner energy strategies are a case in point. In Europe, the effort to set up rapid charging stations for electric cars was a game-changer in enabling more extensive and rapid adoption. In Asia, the campaign by public–private sector partnerships to design and optimize efficiencies in urban areas has already provided tangible returns. In Africa, which has benefited from leapfrogging and then customizing technologies, the environmental footprint has been reduced dramatically. In the Middle East, significant strides have been made to define society and the economy “beyond oil”. And in the Western hemisphere, the pervasive adoption of renewables, especially solar, has transformed the energy calculus.

Decades of recalcitrance by policy-makers could not be erased with a sharp turn, no matter how well advised. Neither could the years of eroded public trust. Beyond that, citizens also directed their frustration at big business, which many held responsible, not only for environmental degradation, but also for globalization practices, growing levels of income inequity, squandering of resources, exploitation of workers and putting private interests ahead of the public good. Attitudes have come to a boil regarding “unresponsive” governments and “predatory” global corporations.

All this helps to explain why a hyper-localization campaign took off throughout the world a few years ago. The inflection point occurred in 2022 when, in the face of incontrovertible evidence, leaders failed once again to reach agreement on how to address the challenge of climate change. Once again, the listless economic environment prevented them from doing the right thing. A terrible health scare involving imported food affecting large parts of Europe added fuel to the fire.

The world rapidly became more locally focused. The preference for locally produced food expanded to manufactured goods, as consumers increasingly wanted to know where their products were made, by whom and using what resources. A major market of high-end, customized products that are produced domestically has since developed, aided significantly by advances in additive manufacturing techniques that can now be deployed by small artisanal producers and small- and medium-sized enterprises (SMEs). Localization took the place of globalization as the word capturing the zeitgeist of the time.

Public attitudes have come to a boil regarding "unresponsive" governments and the "predatory" practices of global corporations. Citizens have simply had enough.

The new economy, driven by digital natives who have lost confidence in government and business institutions, pushes for a "distributed" governance model in which power devolves to the local level. The pressure is for strong support of local production, customization and the pursuit of the circular economy. In effect, it is the end of mass anything. The economies of scale of the past now carry a prevalent stigma. One young political leader, especially popular with Millennials and with a large following, pointed to the need for an "unplugged" economy of service.

Years ago, in 2016, it became clear that multilateral agreements such as the Trans-Pacific Partnership and Transatlantic Trade and Investment Partnership were beyond the pale. The realignment that year was the beginning of a retreat from globalization, generated more out of concern about competiveness than by the state of the environment. The trade tensions that followed drove down world economic growth, especially among those countries with a substantial external economy. It was clear, however, that many people would prefer to pay a premium for locally grown and produced products than to benefit by paying less for the same kinds of products from abroad.

Ultimately, this phase served to open a new era of social and economic policy. Government subsidies aimed at boosting local industry and protecting it from foreign competition were set in place across several major economies. From the clothes dryer to the dinner table, from the garage to the workplace, local solutions came to the fore. The trend served to reorient the nature of innovation, diverted the trajectories of the major technologies, and even curtailed some such as CRISPR-ca9[3] altogether, out of concern for the potential implications of their misuse.

Trade in product design saw an appreciable boost, by virtue of its ease in crossing boundaries. Furthermore, middle-income countries saw an opportunity to invest in workforce skills and promoted themselves as design-service hubs by offering a lower-cost labour base. Lower-income countries struggled as their global niche as low-cost producers continued to erode.

This dramatic shift away from the dominant global economic paradigm led to a decline in global economic growth. In the past 10 years, from 2020 to the present, the average annual growth rate has averaged 2.5%. The localization phenomenon has brought with it the return of inflation and potential stagflation. Historians have pointed to the 1970s and 1980s as a precedent. However, proponents now call this "the clean march", and argue that "lifestyle income" – the psychic income that comes with higher levels of environmental stewardship and social inclusiveness – represents the equivalent of another 200 basis points. One movement leader once asked, "Where do you want to live: in a toxic, ungoverned, unequal jungle, or in a healthy, positive, and enlightened place for working and raising a family?"

3. A genome editing technology that enables the editing of genome parts by removing, adding or altering sections of DNA.

Governments focused their energies on addressing the labour challenge, but public–private partnerships had the biggest bang for the buck when it came to training and deploying the workforces for the devolved economy. To be sure, there were no silver bullet solutions. Nevertheless, imaginative, information-technology-enabled approaches were able to fill the employment gaps and increase the level of environmental responsibility. The key lay in the education sphere. It started with an aggressive K–12[4] programme to instil localization values in children from a young age, and then provided ample opportunity for them to pursue higher education.

The new economy, driven by digital natives who have lost confidence in government and business institutions, push for a "distributed" governance model, in which power devolves to the local level.

In the final analysis, the localization movement and the repudiation of key elements of globalization changed the fundamental production outlook. There were two main shifts:

First, value chains were realigned as a result of local production and customized products. Smaller companies prospered, and there was an explosion of entrepreneurial activity as barriers to entry for globalized firms were raised significantly. Demand for customization put immediate pressure on larger manufacturers geared to serving mass markets. Other large organizations used their scale to specialize in more commoditized products, ceding high-end positions to SMEs. The supply chains for all companies shifted greatly, since sourcing of input materials, production of products and selling into the market are all local in nature.

Second, it pushed to the fore additive manufacturing and 3D printing, which by its very definition conformed to the custom and local elements of the prevailing public movement. The technology has continued to evolve.

Hardware and material improvements alongside print optimization software have advanced to new levels, allowing for faster print speeds. Content libraries have also grown considerably, allowing for differentiation of products. Greater access to big data and analytics techniques has allowed nimble SMEs to create customized products in areas as diverse as clothing, food and electronics.

Another major development in production was the arrival of mobile urban manufacturing units. These small and autonomous manufacturing cells have been shipped to countries to develop customized content with the help of local labour. They are the antithesis of a big, far-away plant, and may leverage lower labour and other costs, in so doing conveying an altogether different image of the production process.

The "100-mile rule", as it has come to be called, is the *sine qua non* for economic activity and production. The factories that do exist, located underground in urban centres, almost lights out, are characterized by "appropriate technologies" to address issues of production problems and hyperefficient logistics, regional hubs with specialism, improved work conditions and increased handcrafting.

4. K–12 comprises the sum of primary and secondary education in many countries, including Australia, Canada and the US.

Meanwhile, companies have been highlighting a “human at the centre of everything approach” to satisfy the localization requirements. This implies not only higher levels of human–machine coordination, but also better, faster and more sustainable decisions by middle management. At the same time, it alleviates the considerable pressure that automation has placed on labour in the years prior to the paradigm shift.

The resulting focus on localization has provided production opportunities for large, low-cost producers on the one hand, and smaller, high-end manufacturers on the other. Countries with large consumer bases have benefited as their internal demand was able to weather reductions in global trade.

Exporting countries have generally suffered, although some major new business hubs have sprung up in medium-income countries.

The strong and lasting localization movement would have surprised prognosticators a decade ago. Not now. The circumstances for the significant social shift are compelling and enduring. In the face of unrelenting and alarming environmental pressure and anaemic government responses, global economic growth and intergovernmental cooperation have both slowed. They simply no longer reflect the social priorities at work.

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Appendix
Summary of scenario elements in the Future of Production 2030

Overview of the key drivers

	Disrupted	Deterred	Damaged	Devolved
Technology and innovation	– Rapid technological advancement	– Isolated technological progress	– Impeded automation and technological proliferation	– Slower adoption of technology
Regulations and governance	– Policies successfully enable rapid technological/ economic progress – Cross-border diffusion of innovation	– Regulation dictated by overall tension between political systems – Weakening of international intellectual property protection	– Economic nationalism – Statist policies – Industry protection and subsidies	– Devolution of policy-making to local level – Public trust in global frameworks wanes
Global economy, trade and investment	– Renaissance of innovation – Global trade produces long boom and reduce global poverty	– Cyber conflict between major powers reduces global economic growth rate	– Beggar-thy-neighbour economic policies slow growth	– Decline of cross-border trade produces marginal growth – Rise of shared economy/"tiny" consumer
National resources and sustainability	– Renewable energy boom propels development and sustainability in developed and developing countries	– Increasing environmental damage – Only incremental international cooperation	– Nationalist competition trumps environmental concerns – Rapid and profound environmental damage	– Some moves towards sustainability and circular economy – Emphasis on food security and local production
Human capital and skills	– Moderate success in upskilling workforce and effectively addressing dislocated workers	– Government support stabilizes some segments in manufacturing, while others are at risk of dislocation	– Combination of worker populations within protected industries while others are at risk of acute dislocation	– Embrace of local work and technology – Persisting problems with efforts to achieve full employment
Consumer expectations	– Pervasive and rapid adaptation of technology waves – Widespread consumption of the diverse products	– Segmented consumption patterns – High-cost digital and other technology products contrasting with non-digital	– Low-trade, low-growth environment – Fewer and more expensive products	– Consumers reframe their preference to "localized" products – SME products at a premium

Impact on production

	Disrupted	Deterred	Damaged	Devolved
Firms	– Explosion of contract manufacturing – Firms deliver complex products with flexibility and unbeatable time to market	– Widespread technology adoption delayed by vertically integrated "super majors"	– State enterprises assume responsibility for critical sectors – Economic statism driven by political prerogative, not markets	– Decoupling of scale and costs helps small- and medium-sized companies to thrive
Factories	– Blurring of hardware and software reduces marginal production costs to zero – R&D, marketing and data become key drivers for most industries	– Reversion to traditional factory environment, with limited automation and emphasis on human capital	– Factories struggling through limited markets, sporadic inputs, inefficient domestic supply chains and heavy government intervention	– Factories characterized by "appropriate technologies", hyperefficient logistics, improved work conditions and increased handcrafting
Goods	– Highly personalized products – Creation of new value chains	– More limited selection of products	– Deteriorating selection and quality of products – Consumption shifts to staples	– Services taking up larger share of value creation – Successful leveraging of technology to deliver complex products/ services
Workers	– New levels of interoperability between humans and machines	– Cyber conflicts discourage worker entry to industry	– High unemployment leads to massive public works projects	– Premium placed on "rehumanization of production"

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