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Digital technology determines how (and even whether) people work as much as it determines how information produces economic activity.

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The Next Phase in the Digital Revolution:

Intelligent Tools, Platforms, Growth, Employment

DIGITAL PLATFORMS IN the computing "cloud" are fundamental features of the digital revolution, entangled with what we term "intelligent tools." An abundance of computing power enabling generation and analysis of data on a scale never before imagined permits the reorganization/transformation of services and manufacturing. Here, we expand two central issues raised in our 2016 article "The Rise of the Platform Economy."[13] First, will the increased movement of work to digital platforms provide real and rising incomes with reasonable levels of equality? The productivity possibilities of the digital era are just coming into view. The consequences will be a matter of policy and corporate strategy. Much will depend on how intelligent tools, including big data analytics, artificial intelligence, robotics, and sensors will coalesce into systems that appear to be nearly autonomous. The goal of firms could be to simply displace work and remove human intelligence from work tasks. Alternatively, it is possible for intelligent tools to help augment intelligence and capabilities, supporting rather than displacing workforce abilities. Moreover, as communities, is it possible to choose the kind of society that will result from the digital "platform economy." Digital technology does not, in and of itself, dictate a single answer. The increasing diffusion of intelligent tools has already exposed tension between public governance and private governance of platforms. The significance is that a platform's operation sets the rules and parameters of participant action. Digital platforms are regulatory structures and, thus, governance systems. Policy cannot just adapt to the emergence of the digital economy and society. Policy choices are indeed part of the technological trajectories themselves.

The Basics

It is not necessary to review the digital technologies themselves. The goal is rather to explore their economic and

» key insights

- **Social and political choices determine, in part, whether deployment of intelligent tools and platforms will augment human skills or replace humans as workers.**
- **Digital platforms are regulatory and governance structures that set the rules and parameters for social and economic activity.**
- **Intelligent tools simultaneously replace, transform, and create work.**

PHOTO BY JOHN JAMES/UNIVERSITY OF BIRMINGHAM

Autonomous robot (Betty) developed at the University of Birmingham for work as an office monitor.

social implications. This phase of the digital era rests on cloud computing facilitated by the increasing abundance of inexpensive computational power, storage, and transmission resources. Gradually, but inexorably, the exponential increase in computing capabilities, noted in popular media through reference to Moore's Law and the consequences of doubling processing power every two years, and with data storage on a roughly similar trajectory, has changed the game, even as these dynamics continue their rate of change. Lifting constraints opened the current digital era, as characterized by platforms, big data, algorithmic power, and intelligent tools.

Consider platforms. Digital platforms, which we define later, are digital algorithms and software structures that run in the cloud and operate on data. The platform story is closely related to the digital transformation of services and, more broadly, manufacturing as well. Rule-based information and communication technology

(ICT) applied to service activities has initiated an algorithmic revolution. As Zysman[27] argued in 2006, service activities themselves are changed when they can be converted into formalizable, codifiable, computable processes with clearly defined rules for their execution. Searching for fresh language to describe a complex process, Zysman[27] labeled this change the "algorithmic service transformation facilitated by ICT tools," describing it, "Services were once seen as a sinkhole of the economy, immune to significant technological or organizationally driven productivity increases. Now the IT enabled reorganization of services, and business processes more generally, has become a source of dynamism in the economy."

Consider how the physical cranes used in ports are often sold in a bundle with port management services, and sensor-enabled farm equipment is sold bundled with soil- and plant-management services. Here, the things are embedded in services, increasing the value of both the equipment and the services to the customer.[20]

Today's digital platforms consist of software processing data in the cloud. As Fortran and Unix pioneer Stuart Feldman explained to us in a recent conversation, a computer science definition would be "that platforms provide a set of shared techniques, technologies, and interfaces to a broad set of users who can build what they want on a stable substrate." As conventionally used, the term "platforms" refers to multisided digital frameworks that shape and intermediate the rules participants follow to interact with one another.[10,20] Platform power is generated through direct and indirect network effects that can result in winner-take-all dynamics, conferring enormous power to the platform owner. Platforms are thus algorithm-enabled "cyberplaces" where constituents can act, interact, and transact.

These actions are highly diverse, whether categorized by market, social function, or technical character. Each platform involves its own diverse computational and market issues and questions. Goods platforms from Alibaba, Amazon, and eBay link buyers to sellers and raise questions involving, say, the power of the underlying platform in the supply chain.[14] Service platforms, in the form of labor-market-exchange platforms (such as TaskRabbit, Uber, and Upwork), connect buyers and sellers of people-delivered services, raising potential labor market conflicts, while forcing the rethinking of traditional labor market regulations. That is, there are B-to-C platforms, sharing platforms that are often C-to-C, and indeed B-to-B, including IoT arrangements, as well as platforms for Industrie 4.0.

The conundrums raised are diverse and particular to each platform and industry. For example, taxis that are publicly regulated cannot discriminate among potential customers, but can Uber drivers who are indeed merely contractors discriminate against potential customers? Hotels must obey land-use rules and not discriminate among potential guests, but what about Airbnb providers? And who should enforce anti-discrimination laws and regulations—private contractors, platform owners, or the government? Who should be responsible for inspecting the algorithms driving business operations and performance? Who should have access to and control over the data private firms collect as part of their business operations and for what purpose? In terms of industrial production, the Internet of Things, a polyglot category of objects linked through cyber connections, raises even more questions about industrial standards, rules, and ownership of machine-generated data. Will standards-setting bodies set and control the industrial standards on production platforms? Will private firms create and secure adoption of de facto standards that control these interfaces? Such decisions already profoundly affect competition among producers of industrial equipment. Finally, since all such IoT-related machines are constantly producing data, who should own or have legal access to it? The market structure and relative balance of power among, say, Cisco, General Electric, Google, Huawei, John Deere, Komatsu, Siemens, small and mid-size firms, and everyone else will turn on the answers.

Kurt Vonnegut's 1952 novel *Player Piano* on the "privilege" of work in an automated economy.

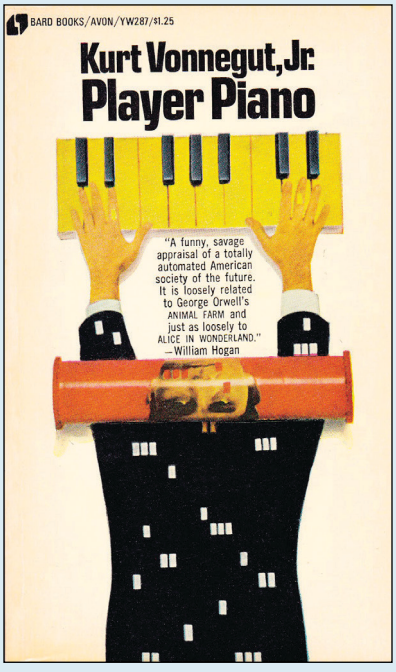

IMAGE COURTESY OF BARD BOOKS

Cloud computing provides the computational architecture and structure for an array of interactions.[15] The consequences for the user, not the "how" of cloud computing for the provider, are our focus here. Providing "computing clouds" favors scale. Scale favors players with the most demanding data processing needs and capabilities. Indeed, cloud architectures first emerged as companies like Amazon, Google, IBM, and Microsoft provided for their own computer needs, then sold excess computing capacity and services in a variety of packages. Cloud computing havs matured to deliver computing services—data storage, computation, and networking—to users at the time and location and in the quantity they wish to consume, with costs based solely on resources used. Powerful computing resources can now be assembled, orchestrated, and deployed as needed. For those purchasing cloud computing as a service, the data center is no longer a capital cost, it is now simply a *variable* operating cost. This makes it possible to create, experiment with, and launch platforms at dramatically lower cost. Start-up costs are reduced, and the costs of expansion of computing resources can be managed "as needed."

In more formal terms, cloud computing expands the availability of computing while lowering the cost of access to computing resources, sometimes to where it can be paid with an

individual's credit card, depending what one wants to do. This process eases access to inexpensive elastic computing resources and scaling for startups and experimentation within larger companies. The chief information officer is thus no longer a choke point for access to computing resources. One might say the cloud reduces the importance of the cost of computing when calculating the cost of starting a firm or experimenting with a new application. Organized effectively, it can speed application development and deployment. In effect, value moves up the value chain, from provision of basic computing infrastructure to creation and deployment of applications.

What sort of world will we build with platforms, data, and intelligent tools? How will value be created, and who will capture it? The pioneers of the digital age, including Robert Noyce at Intel, Bill Gates at Microsoft, and Steve Jobs at Apple, thought they were creating a world of possibility and opportunity and indeed unleashed a new way to interact with the world. Even earlier there were skeptics. For example, Kurt Vonnegut's 1952 science fiction novel *Player Piano*, based on computing machines using electronic tubes, not integrated circuits, reads like the dystopian literature seen in today's academic and popular press.[4,5] In the world Vonnegut envisioned, work was a privilege, and, except for a privileged few who ran the system, jobs for the masses consisted of Works Progress Administration-like infrastructure repair and the military.

What kind of future will result from intelligent tools? Some part of the answer begins with these questions: What happens to productivity? How quickly will changes in jobs and work take place? What sort of jobs will be created and for whom? How are labor markets being reorganized? And who wins (and loses) and captures whatever gains there might be?

Deployment of technology is as crucial to productivity as technology itself.

Productivity Debate

Since the mid-19th century, basic standards of living have been transformed, and the productivity of advanced economies has risen dramatically. A core debate concerns whether that historic run is continuing. ICT is profoundly transforming our lives. And yet economist Robert J. Gordon has argued that the basic changes in transport, housing, medicine, and the like that took place from 1870 to 1970 were even more profound for productivity and standards of living.[11]

Productivity, however formally defined and measured, matters, since, at its core, it represents an organization's increased ability to generate goods and services from a given endowment of productive resources. We are collectively richer not just because of savings and investment, though they are essential, but because of sustained innovation affecting what we do and how we do it. Gordon and others have said that ICT, despite the hype, actually *has not* resulted in sustained productivity increase in the past decades.[11] Setting aside the observation that much of the value of ICT in the consumer marketplace, from search to social media, is provided free, in exchange for users being subject to advertising, and consequently the benefit may not be measured effectively. There have been debates over measurement before.[6] Let us accept for the moment Gordon's finding that the drop-off in the rate of productivity increase since 1972 is real. His conclusion that after 2007 labor productivity grew at no more than 1.3% annually is sobering, particularly as this productivity growth was significantly slower than the 2.0% growth from 1891 to 2007. A core question is not why growth slowed but why and what ICT might have to do with it.

Transformative technologies, those involving a broad swath of activities as they are introduced, are believed by economists from Joseph Schumpeter[23] to Carlota Perez[21] to drive rapid growth and productivity. The historic roles of steam engines, railroads, and electricity demonstrate the effect of these powerful general-purpose technologies.[12] The core argument by Gordon and others is that ICT, beginning with the microelectronics revolution, has not had the impact of earlier transformative technologies. That contention has two components: the proposition that ICT has had only limited scope in the economy, to, one might say, entertainment and the acceleration of financial transactions; and that the technology wave has passed, so the effects are complete and proved to be limited. Both assertions are open to debate, if not simply mistaken.

ICT is certainly a powerful general-purpose technology that laid the groundwork for Schumpeterian transformations in production organization, product design, and business models that is today recasting a significant portion of the world economy. The early phases of the ICT revolution principally affected services that, at their core, are about information, involving communications, finance, media, and insurance.[28] ATMs substituted for tellers in one existing business model, and while high-frequency trading on Wall Street radically changed competition in the financial sector, the basic business models were unchanged. In other sectors, established business models are indeed being overturned. The offshoring of service work to locations like India and the Philippines was possible only because content was digitized. When media content was converted to digital formats and easily distributed, traditional business models were upended. More important, in the early Internet phase of the digital revolution, ICT-enabled services, as mentioned earlier, began to be extended to "everything," and the related business models often changed character. Examples of such change abound, some well known, others less discussed in the business press and scholarly research. For example, airplane engines, and indeed truck tires, can be sold as services with charges related to use. Finally, in 2018 the impact of online purchasing, as well as other forms of e-commerce, are only beginning to be felt in retail, as brick-and-mortar stores are closing at an astonishing rate. This will likely have a positive effect on national productivity but a negative effect on employment.

The platform phase is the latest step in this unfolding story of the deployment of ICT technologies. For the moment, consider platforms. Platforms, digital and multi-sided, provide new ways for users, who could not previously reach each other and thus could not previously form a market, to interact. The Internet of Things, Internet of Everything, and Industrial Internet amount to new ways for sensor-enabled objects to be controlled and interact through platforms. The platforms themselves facilitate aggregation and analysis of data with the intent of controlling systems and actions. We are entering a world that will increasingly be organized through the interplay of algorithms and data. It will be a data analysis-based economy and society where observation and interpretation of our individual behavior and optimization of our physical systems will be based on computation.

Capturing the promise of the technology is as much a political problem as it is a narrowly economic constraint.

The breadth and dimensions of the effects of platforms, sensor-based system, and data analytics are breathtaking. In the prosaic world of industry, Cisco, General Electric, IBM, Huawei, and Siemens, through marketing and business strategies, highlight industrial applications, from energy management to pipelines to aircraft management. For example, General Electric says its goal is to integrate ICT and data to provide solutions across industries, including manufacturing, aviation, transportation, power generation, health care, and energy.

The provocative German discussion of Industrie 4.0 (https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/industrie4.0-smart-manufacturing-for-the-future-en.pdf) envisions how data capture and analytics will reform and reorganize manufacturing and supply chains. German global competitive advantage in manufacturing depends on skilled labor and specialized small- and mid-size firms.[12] The question the original Industrie 4.0 study posed in Germany and elsewhere is how to craft cyber tools in a platform economy to support and sustain skill-based competitive advantage. The most important point is that we are in the midst of a transformation, not the end.

Skeptics like Gordon might ask where is the concrete evidence that this round of innovation will reignite rapid productivity growth similar to the period that ended in the 1970s? There is an array of alternate explanations for the productivity slowdown that is unrelated to technology per se. Our purpose here is not to review or evaluate the rich literature on productivity but suggest the debates that will result from the economic character of the digital transformation.

Central to this discussion, productivity is not simply a technical matter but a real-life story of the reorganization of communities and work to generate new productivity gains. Deploy-

ment of technology is as crucial to productivity as technology itself. One line of argument among economists is that the technology-diffusion machine in the advanced countries has broken down. For example, a 2016 Organisation for Economic Co-operation and Development study[1] found the productivity frontier has been pushed outward but the best practices are not being implemented broadly in the economy. It found the leading 10% of global firms in each sector has had significant and steady productivity increases in the 21st century, while the other 90% continues to lag.[1] The problem for society becomes one of deployment and diffusion, business practices, and structural policy, not the inherent possibilities of the technology.

The OECD results suggesting a gap between the frontier and the rest is still being debated but have raised important questions about the role of intelligent tools in addressing the productivity slowdown. Does the slow productivity growth in the economy as a whole exist because of slow diffusion of leading technology and organizational/business principles? If the diffusion machine is indeed broken, is the reason resistance, overregulation, policy, or incapacity at the level of the individual firm? As Perez[21] and the Schumpeterians suggest, it might be that productivity moves in jumps, as new paradigms of organization and innovative technologies combine to permit new plateaus, a conclusion that would counsel patience. Each jump to a new plateau implies both production reorganization and new forms of work and work organization.

Are the political obstacles to the diffusion of ICT technology and organizational principles different in this era of intelligent tools from that of steam or electricity? As the Luddites showed in their reaction to the self-acting "spinning mule," technology deployment and diffusion is rarely a simple or conflict-free process. The mechanization of U.S. agriculture proceeded relatively more smoothly, because the mass production-driven economic growth in the Industrial Midwest and California could absorb the surplus labor. The politics of 21st century growth already involve deep dislocations in already prosperous well-organized societies that will continue to be difficult politically. Capturing the promise of the technology is as much a political problem as it is a narrowly economic constraint, suggesting policy and political action rather than descent into economic pessimism.

Some economists contend that winner-take-all tendencies in the digital economy are at fault for dislocations.[5] Are the leading 10% of firms at the productivity frontier because they have dominant market positions unavailable to the other 90%? Along a different line, outsourcing of business services (such as janitorial or even secretarial and bookkeeping) might well keep high-productivity activity in core firms and transfer low-productivity activities to suppliers. If this is the case, the whole system might be no more productive but significantly more unequal.

In sum, we are in the midst of an ICT-powered industrial revolution. The effects emanate from a small set of information-based sectors or leaders at the frontiers of effective deployment. We can decide later whether the period 1970 to 2018 brought as profound a change in our way of life and standard of living as did the period 1870 to 1970. It is clear that the impact of intelligent tools on productivity will depend not just on the technological advances but on the capacity to deploy and diffuse them. It is almost certain that sustainable productivity increases will be a necessary though likely insufficient condition for increasing employment and wages.

Does Work Have a Future?

Consider now the concrete question of jobs and work separately from the abstraction of productivity. Who will work? Who will be employable? What will they do? How might they be compensated? How will labor markets be organized? The jobs question is as difficult to sort through as the productivity question, because it is impossible to predict what new work will arise as the economy changes. Labor markets will be created and transformed by platforms and intelligent tools based on the character and organization of work.

Platforms and labor markets. The current focus on digital platforms and labor markets has principally considered the ways work is organized and compensated. The emphasis has been on matching work and workers and the belief that increasing numbers of jobs are being converted from stable work to "gig" employment. This logic understates and improperly frames the issue.

Platforms, from Amazon and eBay to Uber and Upwork, and even to YouTube, are built on discovery-and-matching mechanisms, between jobs and employers, clients and contractors, sellers and buyers, and, most abstractly, creators, consumers, and advertisers. The implication is that if only more individuals could participate in the market or if only good matches could be made more easily, growth would accelerate and well being for the vast majority of workers would improve. The premise is that digitization has transformed employment relations between employer and worker (capital and labor). The policy concern here is that moving work to platforms risks facilitating a redefinition of the core of the economy, from employment relations to gig and contract relations.[26] Despite contentious debate among scholars and political figures, there is also an argument about how much has really changed over the past few years; for example, one study[8] suggested that in June 2016 only 0.90% of U.S. adults actively earned income in the "online platform economy." Are there more such market relationships or just that such relationships are visible now that they are online, rather than signaling a real increase in contingent work?

Academic research on the transfer of work to digital platforms, and the accompanying transformation of once-stable employment to more precarious work or the elimination of entire work categories altogether, while diverse and expanding rapidly, often focuses on a single firm or sector, whether taxis and Uber or encyclopedias and Wikipedia. The current public fixation on Uber and Airbnb is understandable, as they directly challenge two significant traditional industries—transport and lodging. Both involve conversion of consumer goods, cars, and residences into producer goods and thus affect existing labor relationships and markets. If

we extend the scope of consideration to, say, YouTube, which has helped transform the entertainment and self-help-publishing industries or Amazon's self-publishing book business, which is helping reorganize publishing; both convert the labor market relationship to one in which creators "consign" their work to the platform, revealing yet another vector of industry reorganization and with it a labor-process change. Viewed this way, the influence of digital multisided platforms on the overall economy is far greater than the narrow focus on Uber and Upwork, and even YouTube, would suggest.

Evaluating the platform economy requires that we project beyond the most evident applications and their effect on the workforce and their employers and consider the ecosystems they organize.

ICT and the reconceptualization of productive activity. Any discussion of work and jobs must consider how production of goods and services will be reorganized as ever more sophisticated ICT is introduced.[28] Even as much attention focuses on factories, warehouses are also being automated, and service tasks are being assigned to "smart" programs and robots. One set of arguments, particularly as reported in the popular press, focuses on specific technologies, including AI, robotics, and 3D Printing. A second set, best represented by the now iconic German analysis Industrie 4.0 considers how governments, labor unions, and companies can respond to preserve competitiveness and augment worker skills and capacities, even as the very character of production changes.

A third set of labor-market studies focuses broadly on the consequences of automation and suggests the current digital revolution will indeed generate a world of greater unemployment, more unskilled workers, and greater inequality.[5] Many of these studies highlight concerns about the destruction and devaluation of work and skills. However, following studies from a number of well-known consulting firms, the conclusions concerning employment are less clear. Implications run from urgency—job tasks for potentially tens of millions of workers will be transformed soon by automation or complacency—as the displacement will be at a scale compatible with ordinary structural change in the economy. The differences in conclusions—from urgency to complacency—depend on the varied judgments of what can be automated and what might be economically feasible to automate, the data sources used to estimate the possible changes, and the timeframe of the structural changes being observed.

Komatsu excavator uses computation to calculate the correct angle of its digging blade.

The outcomes concerning work and skills ultimately depend on how the new emerging intelligent digital tools are deployed. Moving the technology frontier outward promises new possibilities while eliminating existing ones.[7] Each set of possibilities often includes distinct implications for value creation and capture. The new frontier, though, does not entirely determine the structures and organizational forms through which a technology might be deployed. If the goal is to, say, reduce carbon emissions, a society can electrify its vehicle fleet, then "decarbonize" the resulting increase in electricity demand with renewable energy, thereby moving to an entirely new energy system. Alternatively, and more in keeping with what the history of technology transitions suggests,[2] a firm or even a whole society can introduce a transition technology, as the Japanese automakers Toyota and Honda did with the Prius and Insight hybrids, respectively. Hybrids offer opportunities for improving technologies (such as through batteries and electric-engine systems for automobiles) while staying within the existing carbon-energy system infrastructure and preparing for the expected transition.

Rather than centralized factories or decentralized customization, new approaches are certain to emerge to production organization, and with it new strategies for entrepreneurship and requirements for worker skills. It is possible no single production system will dominate in the 21st century but rather a variety of ways to organize productive activities, as work is continually reconstituted and value chains reconfigured. Mirroring what might become a range of organization models, a remarkable variety of employment arrangements could emerge, too.

Pondering such arrangements leads us back to the question of the effect of intelligent tools on the tasks and work people do for a living. A focus by economists and business leaders solely on the jobs that may be displaced or transformed by intelligent tools hides the opportunities that are certain to emerge and the innovative possibilities that may be unleashed. Whether it is product designers for 3D printers in the maker movement or

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video creators on YouTube, new work, tasks, and sources of income are being created. Moreover, the innovation dynamic can never be totally "automated," remaining for the foreseeable future a domain of human inventiveness and initiative. This is particularly true given that digital resources (such as open source software and cloud computing resources and capital for innovative activities) are more available than ever before.

A crucial question for society, however, is whether this new world will include only employment and reward for the highly trained top 10% of society, those lucky enough to be anointed YouTube "stars," have their app go viral, start a new firm later acquired by an existing firm, or be employed in a core firm. Where income will come from for those with more modest training and education not blessed with inherited status, born with innate and recognized intelligence, or just not lucky? Some, including Carl Benedikt Frey and Michael A. Osborne[22] have argued that broad swaths of work—standard routine tasks, arguably the bulk of work today—are directly vulnerable to displacement by intelligent tools.[9] However, such displacement is not, in fact, evident. Other research suggests that even routine manufacturing tasks, seemingly most vulnerable to automation, are less routine than they might appear at first glance. Moreover, the automation itself opens new shop-floor-level domains requiring judgment and augmented human capabilities.

An alternate view maintains that computation can augment human intelligence and capabilities. There is already evidence that even routine work can be augmented. Often, however, such augmentation involves contradictory elements. For example, in Japan, where there are shortages today of skilled operators of heavy equipment, equipment manufacturer Komatsu introduced an excavator that uses computation to calculate the correct angle of the digging blade so it does not dig too far. This control enables even relatively inexperienced operators with lower skill levels to work effectively in situations where previously only highly experienced operators could be used.[3]

The jobs question is as difficult to sort through as the productivity question, because it is impossible to predict what new work will arise as the economy changes.

In any discussion on augmenting human capabilities, the user interface is critical. Programs, websites, and apps are essentially user interfaces and thus augment and empower while structuring human capabilities and activities. Standard office applications (such as Word and Excel) designed and built for personal computers, contributed to the diminishing demand for secretaries and concurrent increase in staff assistants and computer specialists. The user interface profoundly influences who can use and deploy computing power.

Whether and how computer systems augmenting workers' skills and knowledge will be developed and deployed remains an open question, to be discovered sector by sector, production phase by production phase. Indeed, the required mix of skills will depend on how ICT tools are deployed and on the user interfaces that are developed.

In the choices businesses must make about the design, development, and deployment of the tools they use for automation, one question is crucial: Are workers an asset to be promoted and developed, partners in competition with other firms? If workers are strategic, then a primary challenge is imagining and investing in tools, including user interfaces, that make all workers more productive, effectively a strategy for augmenting intelligence. To illustrate, Ton[25] showed that even in the commodity retail business, a profitable strategy can be a good-jobs strategy involving investment in workers and organizational strategies to help those workers develop their capabilities and achieve their potential.

The implication is that if society invests in technologies, business models, and companies subscribing to the belief that intelligent tools will inevitably displace work, with investment after investment made to find ways to substitute capital for labor, then a dystopian outcome is inevitable and with it a road toward digital displacement on a mass scale. The prophecy of ICT displacing human beings will thus be self-fulfilling. In contrast, if a concerted effort is made to discover how to use ICT to augment intelligence, upgrading jobs throughout the work spectrum, then perhaps these digital resources can be harnessed to build a

broadly better future. So government and employers alike must ask: Is there a strategy for using computation to augment human intelligence? And how can we redesign work to leverage human cognition and creativity?

The outcomes depend on societal choices and vision and how technology is deployed and used. Outcomes are not inherent in the technology itself. The balance is yet to be determined. A difficulty is that it is likely easier to identify the specific problems for which intelligent tools can displace jobs than try to understand the ways worker capacity might be augmented. It should be possible to design research initiatives to develop and elaborate a future in which the effect on workers is a key factor to be considered. The continuing progress of intelligent tools will, if it simply displaces work and absent the retraining and creation of new employment opportunities, create significant social upheaval.

To understand the effect of ICT on work tasks and jobs requires that we examine the reorganization of production and the transformation of work itself, as well as labor-market dynamics. It is, in the end, a single woven fabric. If intelligence augmentation requires new skills or integration of work in new ways, who in the platform economy will invest in developing worker skills and encouraging work redesign?

The innovation dynamic can never be totally "automated" and remains for the foreseeable future a domain of human inventiveness and initiative.

Policy and Politics for the Platform Economy

The sweeping changes brought about by digital technologies are prompting debate throughout society about the institutions and rules of the economy and society.[18] Most fundamental, how will the benefits of the promised new productivity be shared among all members of society? The political question is: What sort of world is emerging, as platforms and intelligent tools continue to progress?

The policy agenda is long and diverse, so consider the following comments to help organize the discussion. In the event of technological shifts as large as this one, various sectors and regulatory issues are affected, but the ongoing debate and discussion are siloed, despite the fact that decisions in one regulatory realm inform and influence developments and technological trajectories in others.

We note two policy categories:

Platform governance. The increasing power of the firms that own platforms raises the question of how to define the tension between private power and public governance. Far more than with most previous industries, digital platforms are regulatory structures. Even more than in natural monopolies (such as electric and water utilities), today's digital platforms deeply structure the rules and parameters of action available to users. The classic insight in this regard was by American lawyer and constitutional scholar Lawrence Lessig who titled the first chapter in his 2006 book *Code*[17] "Code Is Law"; that is, governance is effectively embedded in the code itself. Firms can introduce platforms that directly or indirectly circumvent existing regulations. If the new service is adopted, as was the case with both Uber and Airbnb, the result can be a direct challenge to state regulatory authority. When the platform occupies an unregulated market or a market in which existing regulations are unclear and difficult to apply, then new platform businesses often compel consideration of new regulations, or, at minimum, new regulatory interpretations. For example, should Airbnb landlords be subject to the land-use regulations and disability-access regulations that apply to hotels? Moreover, platform-based private rule-making in the form of code creates rules that are generally hidden and not available to users or governments for discussion or alteration. These platforms have remarkably powerful social effects. More generally, the choice, and implicitly the debate, is whether platforms and platform businesses should be treated as abstract technologies, technology businesses, or ordinary participants in the particular sectors, whether transportation—Uber—or accommodations—Airbnb? In contrast, Amazon would contend it merely provides logistics support to itself and the users of its platform.

Managing the tension between public interest and private-platform strategies requires that historically siloed and separated debates be integrated into policy discussions. In practice, however, questions about big data, privacy, and security are in-

timately connected. For example, the voice-activated digital helpers from Amazon and Google not only have privacy implications but, because they recommend products and services, also affect marketplace competition.[24] Further, their payment systems could also raise banking regulatory questions. Digital helpers are bound to produce further vertical integration that could also require regulatory intervention. Decisions in one regulatory area can directly influence decisions in other regulatory areas.

The greatest strategic advantage for platform firms is their algorithms and the data they collect. Not surprisingly, these firms claim their algorithms and data are trade secrets not be subject to public scrutiny.

Intelligent tools. To establish a technology trajectory in which intelligent tools contribute to human creativity, one priority for business leaders should be to consider how harnessing computer-human complementarities might create advantage in ways that will be valued and help generate success in the marketplace. Society should thus fund research projects aimed at identifying where, how, and why intelligent tools contribute to augmentation of human capabilities. This research should make possible inferring the kinds of applications and deployments best suited to computer-human collaboration and encourage their development and deployment. Identifying alternatives is difficult. Even more difficult is how to develop organizational strategies that support worker development, augment human capabilities, and amplify human intelligence.

Conclusion

Politics translates debate into social and economic policy. Business leaders, political figures, and workers need to resolve the politics and economics of structural change caused by the movement of social life and economic activity onto ICT platforms and the effect on employment and the work process. In some instances, as with Germany's Industrie 4.0, there will be a coherent national debate, while in others (such as policy in response to, say, Amazon's dominance of online retail) such debate may be difficult to formulate and responses to organize. Policy and politics will be an important force shaping the consequences of the increasing penetration of platforms and other intelligent tools into the fabric of everyone's economic and social life. As existing sectors decline or are transformed, new market leaders will emerge, displacing existing firms, even as new domains and sectors appear. The existing workforce will transform or be pushed aside as new forms of work and new strategies for organizing the production and distribution of goods and services are introduced. There is already a struggle over governance between the public rules and governance embedded in platform algorithms and code. We hope this article provides a framework for a discussion that is only beginning.

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References

1. Andrews, D., Criscuolo C., and Gal, P. N. *The Best Versus the Rest: The Global Productivity Slowdown, Divergence across Firms and the Role of Public Policy.* Technical Report. Organisation for Economic Cooperation and Development, Dec. 2, 2016; http://www.oecd-ilibrary.org/economics/the-best-versus-the-rest_63629cc9-en;jsessionid=9ag8ukcclm7fb.x-oecd-live-03
2. Arthur, W.B. *The Nature of Technology.* Simon & Schuster, Inc., New York, 2009.
3. Asada, H. *Partnership-Driven Business Growth in Komatsu: Autonomous Trucking and Smart Construction.* PowerPoint Presentation. International Partnerships for Advanced Intelligent Systems at Stanford University, Stanford, CA, Oct. 22, 2015; http://asia.stanford.edu/us-atmc/wordpress/wp-content/uploads/2015/10/151022-Komatsu-Slides.pdf
4. Autor, D.H. *Polanyi's Paradox and the Shape of Employment Growth.* Working Paper 20485. National Bureau of Economic Research (Sept. 2014); http://dx.doi.org/10.3386/w20485
5. Brynjolfsson, E. and McAfee, A. *The Second Machine Age.* W.W. Norton & Company, New York, 2014.
6. David, P.A. The dynamo and the computer: An historical perspective on the modern productivity paradox. *American Economic Review 80*, 2 (1990), 355–361.
7. Dosi, G. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy 11*, 3 (1982), 147–162.
8. Farrell, D. and Greig, F. *The Online Platform Economy: Has Growth Peaked?* J.P. Morgan Chase & Co. Institute, New York, Nov. 2016; https://www.jpmorganchase.com/corporate/institute/document/jpmc-institute-online-platform-econ-brief.pdf
9. Frey, C.B. and Osborne, M.A. The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change 114* (2017), 254–280.
10. Gawer, A. and Cusumano, M.A. *Platform Leadership.* Harvard Business School Press, Boston, MA, 2002.
11. Gordon, R.J. *The Rise and Fall of American Growth.* Princeton University Press, Princeton, NJ, 2016.
12. Kagermann, H., Wahlster, W., and Helbig, J. *Securing the Future of the German Manufacturing Industry: Recommendations for Implementing the Strategic Initiative Industrie 4.0. Final Report of the Industrie 4.0 Working Group National Academy of Science and Engineering.* Acatech, Germany, Apr. 2013.
13. Kenney, M. and Zysman, J. The rise of the platform economy. *Issues in Science and Technology 32*, 3 (Spring 2016), 61–69.
14. Khan, L. Amazon's antitrust paradox. *Yale Law Journal 126*, 3 (Jan. 2017), 710–804.
15. Kushida, K.E., Murray, J., and Zysman, J. Cloud computing: From scarcity to abundance. *Journal of Industry, Competition and Trade 15*, 1 (Mar. 2015), 5–19.
16. Lazonick, W. Profits without prosperity. *Harvard Business Review 92*, 11 (Sept. 2014), 47–55.
17. Lessig, L. *Code: Version 2.0. Basic* Books, New York, 1999.
18. Lobel, O. The law of the platform. *Minnesota Law Review 101* (2015), 87–166.
19. Nooren, P., van Gorp, N., and van Eijk, N. Digital platforms: A practical framework for evaluating policy options. In *Proceedings of the Internet, Policy & Politics Conference* (Oxford, U.K., Sept. 22–23). The Platform Society, Oxford, U.K., 2016.
20. Parker, G.G., Van Alstyne, M.W., and Choudary, S.P. *Platform Revolution.* W.W. Norton & Company, New York, 2016.
21. Perez, C. *Technological Revolutions and Financial Capital.* Edward Elgar Publishing, Cheltenham, U.K., 2003.
22. Pfeiffer, S. Robots, Industry 4.0 and humans, or why assembly work is more than routine work. *Societies 6*, 2, (May 2016), 16.
23. Schumpeter, J.A. *The Theory of Economic Development.* Transaction Publishers, New York, 1934.
24. Stucke, M.E. and Ezrachi, A. *How Your Digital Helper May Undermine Your Welfare, and Our Democracy.* University of Tennessee Legal Studies Research Paper No. 324; https://papers.ssrn.com/Sol3/papers.cfm?abstract_id=2957960
25. Ton, Z. *The Good Jobs Strategy.* Houghton Mifflin Harcourt Publishing, New York, 2014.
26. Weil, D. *The Fissured Workplace.* Harvard University Press, Cambridge, MA, 2014.
27. Zysman, J. The algorithmic revolution: The fourth service transformation. *Commun. ACM 49*, 7 (July 2006), 48.
28. Zysman, J., Feldman, S., Kushida, K.E., Murray, J., and Nielsen, N.C. Services with everything: The ICT-enabled digital transformation of services. Chapter in *The Third Globalization? (First Edition).* Oxford University Press, Oxford, U.K., 2013, 1–23.

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