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ABSTRACT

Digital platforms in the computing "cloud" are fundamental features of the present phase of the digital revolution. They are entangled with what we term "computation-intensive automation" (hereafter, CIAutomation). An abundance of computing power enabling the generation and analysis of data on a scale never before imagined permits the reorganization/transformation of both services and manufacturing. This essay explores two central issues. First, whether the increased movement of work to digital platforms can provide real and rising incomes with reasonable levels of equality—whether we face a utopian or dystopian future. We argue that the productivity possibilities of the internet-centric digital era are just surfacing. The consequences will be a matter of policy and corporate strategy choice. In large part, that will depend on CIAutomation, by which we mean all the computation tools that are being deployed and continue to evolve. The deployment goal could be simply to displace work and remove human intelligence from work tasks, but we suggest that this need not be the only evolutionary path. It is possible for CIAutomation to augment human capacities, making for more skilled workforces. Second, as communities, we can choose the kind of society that we create in the platform economy. The digital technology does not dictate the path. Private and public decisions will form the technological trajectories.

CCS Concepts

Computing and business: Automation, economic impact, employment issues

Keywords

automation, cloud computing, digital revolution, employment, platform economy, productivity

1. INTRODUCTION

Digital platforms in the computing "cloud" are fundamental features of the present phase of the digital revolution and are entangled with what we term "computation-intensive automation" (hereafter, CIAutomation). An abundance of computing power enabling the generation and analysis of data on a scale never before imagined permits the reorganization/transformation of both services and manufacturing [32]. This essay expands on two central issues that we raised in "The Rise of the Platform Economy" [28]. *First*, will the increased movement of work to digital platforms provide real and rising incomes with reasonable levels of equality? Here we argue that the productivity possibilities of the digital era are just coming into view. The consequences will be a matter of policy and corporate strategy choice. Much will depend on CIAutomation—an umbrella term for the many tools based on information and communication technology (ICT) now employed, including big data analytics, artificial intelligence, robotics, sensors that in aggregate are coalescing into systems that appear to be nearly autonomous. The goal could be simply to displace work and remove human intelligence from work tasks. Alternatively, it is possible for CIAutomation to augment intelligence and capabilities, supporting rather than displacing workforce abilities. *Second*, is it possible for communities to choose the kind of society that will result from the platform economy? Digital technology does not dictate a single answer. The increasing diffusion of CIAutomation is already exposing a tension between public governance and private governance on platforms [15]. The significance is that a platform's operation sets the rules and parameters of action for participants. In this sense, digital platforms are regulatory structures and thus governance systems. Policy cannot merely adapt to the emergence of the digital economy and society; policy choices form part of the technological trajectories.

1. RECALLING THE BASICS

For this discussion, it is not necessary to review the technologies involved in digital platforms. The goal is to explore their economic and social implications. This phase of the digital era rests on cloud computing, facilitated by the extraordinary and increasing abundance of inexpensive data, computational power, storage, and transmission resources. Scarcity characterized the early days of computing, and that constrained software capabilities [32]. Gradually but inexorably, the exponential increase in computing capacities, noted in popular discourse by 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 a digital era characterized by platforms, big data, algorithmic power, and CIAutomation.

Consider platforms. Digital platforms, which we define below, are, to be cursory, digital algorithms and software structures that run in the cloud and operate on data. The platform story is intimately related to the digital transformation of services. The application of rule-based ICT tools to service activities initiated an algorithmic revolution. As Zysman argued a decade ago, service activities are changed when they can be converted into formalizable, codifiable, computable processes with clearly defined rules for their execution [52]. At that time, in search of fresh imagery for a complex process, we labeled this the "algorithmic service transformation" facilitated by ICT tools. It was summarized in the observation that "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" [52].

The services transformation was accelerated in part by an industrial commodity trap: the emergence of diverse competitors throughout the world producing relatively similar products, components, and modules that competed principally on price [40]. The terms of competition could be transformed when the sale of a product faced with intense price competition is accompanied by the sale of a distinctive service that creates value [38]. This is illustrated by the sale of a crane that becomes the vehicle for the provision of sophisticated software for port management services or the sale of sensor-enabled farm equipment that includes soil and plant management services. Here, the things are embedded in services, increasing the value of both to the customer. At that time, these algorithmic processes driving services were, mainly, internal to the operations of institutions or firms.

Today's digital platforms consist of software processing data in the cloud. As Stuart Feldman explains, a computer science definition is 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, "platforms" are multisided digital frameworks that shape and intermediate the terms on which participants interact with one another [19, 40]. Platform power is generated by network effects that often result in winner-take-all dynamics, thereby conferring the platform owner with enormous power. Platforms are, then, algorithm-enabled "cyberplaces" where constituents can act, interact, or transact.

Those actions vary wildly, whether categorized by market or social function or by technical character. Each platform raises diverse issues and questions. Goods platforms such as eBay, Amazon, and Alibaba link buyers to sellers and pose questions such as those about power in the supply chain [30]. Service platforms, or labor market exchange platforms—such as TaskRabbit, Uber, or Upwork—connect buyers and sellers of services delivered by people, raising labor market issues as well as forcing a rethinking of traditional regulation.

The issues raised are diverse and particular to the platform and industry. Taxis cannot discriminate, but can Uber drivers, who are merely contractors? Hotels must obey land-use rules and not discriminate, but must Airbnb providers do the same? [9] And who should enforce anti-discrimination regulations: the private parties who are contractors, the platform owner, or the government? And if the government regulates, then at which level: national, state, or local? Who should inspect the algorithms driving the businesses? Who should have access to and control over the data that private firms are collecting as part of their business operations and for what purpose? From the vantage point of industrial production, the Internet of Things, a vague category of objects linked through cyber-connections, raises new questions about industrial standards, rules, and ownership of the device-generated data. Will standards-setting bodies set and control the industrial standards on production platforms, or will private firms be able to create and secure the adoption of de facto standards that will control these interfaces? Such decisions will powerfully affect competition among industrial equipment producers. Finally, considering that all these machines will be producing data, who will own or have access to that data? The market structure and relative balance of power among the likes of Cisco, GE, Google, Huawei, John Deere, Komatsu, Siemens, and small and medium-size firms will turn on the answers.

But let us not get too far ahead. Cloud computing architecture provides the power for various kinds of interactions [31]. The consequences for the user, not the "how" of cloud computing for the providers, are our focus. The provision of "computing clouds" favors scale. Scale favors players, with the largest data-processing needs and capabilities. Indeed, cloud architectures first emerged as companies such as Amazon, Google, Microsoft, and Salesforce.com provided for their own computer needs and then sold excess computing capacity and services, in a variety of packages. Cloud computing has matured to deliver computing services—data storage, computation, and networking—to users at the time, to the location, and in the quantity they wish to consume, with costs based only on the resources used. Powerful computing resources can now be assembled, orchestrated, and deployed as needed. And because the "Cloud" permits computing to be moved from a capital expense to an operating expense, the ability to create, experiment with, and launch platforms is radically improved. Startup costs are reduced; the costs of expanding computing resources can be managed on an "as-needed" basis. More formally stated, cloud computing expands the availability of computing while lowering the cost of access to computing resources, sometimes to a cost that is affordable by individuals and payable by credit card—depending on what one wants to do. That makes access to inexpensive elastic computing resources and scaling easier for startups and facilitates experimentation within larger companies. The chief information officer need no longer be a chokepoint for access to computing resources. Put differently, one might say the Cloud reduces the importance of the cost of computing in calculations of the cost of starting a firm or experimenting with a new application. Organized effectively, it can speed the development and deployment of applications. In effect, value moves up the value chain from the provision of the basic computing infrastructure to the creation and deployment of applications.

The key question is the sort of world that we will build with platforms, data, and CIAutomation. How will value be created and who will capture that value? The pioneers of the digital age thought they were creating a world of possibility and opportunity. These pioneers included Bob Noyce at Intel, Bill Gates at Microsoft, and, of course, Steve Jobs at Apple. Indeed, they unleashed a new world, but earlier, there were skeptics. Kurt

Vonnegut's 1952 novel, *Player Piano* [47], based on computing machines that used electronic tubes, not integrated circuits, reads like the dystopian literature in the academic and popular press today [4, 7, 11]. In fact, the line "America in the Coming Age of Electronics" was on the original cover, which makes reference to the now-classic works of Norbert Weiner. In the world Vonnegut foresaw, 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.

Which future will the continuing progress of CIAutomation produce: the future expected by Robert Noyce and Steve Jobs or the one imagined by Kurt Vonnegut? A partial answer emerges from the responses to three questions: (1) What happens to productivity; at what pace is value, particularly value realizable in the market, generated in the digital era? (2) What sort of jobs are created, for whom, and how are labor markets organized? (3) Who wins and who loses, and who captures whatever gains there are?

3. THE PRODUCTIVITY DEBATE

Since the mid-nineteenth century, basic standards of living have been transformed and productivity has risen remarkably. A core debate is in progress over whether that historic run is continuing. ICT seems to be profoundly transforming our lives. And yet Robert Gordon argues that the basic changes in transport, housing, medicine, and the like that took place from 1870 to 1970 were accompanied by even more profound leaps in productivity, as seen in productivity statistics. However, he finds that the impact on productivity in the current ICT era has been far smaller [20].

Productivity matters because, at its core, however formally defined and measured, it represents an increased ability to generate goods and services valued in the market from a given endowment of productive resources. We are richer not just because of savings and investment, though they are essential, but because of the sustained innovation embedded in what we do and how we do it: what and how we produce. Gordon, most notoriously, and others have argued that ICT, despite the hype, has not resulted in a sustained productivity increase in the past few decades [21]. Let us set aside the observation that much of the value of ICT, from search to social media, is provided free of charge, in exchange for the willingness by users to be subjected to advertising, and consequently the benefit may not be effectively measured, or, more exactly, is only measured by the value of the advertising revenue generated. Debates over measurement have been waged before [10]. Let us accept, for this essay, Gordon's finding that the decline in the rate of productivity increase since 1972 is real. His conclusion that, after 2007, labor productivity grew at no more than an average of 1.3 percent per annum is sobering, as this is significantly slower than the 2.0 percent average annual growth from 1891 to 2007. The core question in this paper is not whether productivity growth has been slowing, but why, and what ICT has to do with that.

Authors from Schumpeter [43] to Carlota Perez [41] believe that transformative technologies, which touch a broad swath of activities as they are introduced in an economy, drive rapid growth and productivity. The historic role of steam, railroads, and electricity provides evidence of these characteristic and powerful general-purpose technologies [25]. The main argument made by Gordon and others is that ICT, beginning with the semiconductor revolution, has not had the impact of earlier transformative technologies. That contention has two components: first, that ICT has had only limited scope in the economy, one might say, limited to our entertainment and a bit of convenience in finance; second, that the technology wave has passed, so the story is done and has been shown to be limited. Both assertions are debatable, if not simply mistaken.

First, ICT is a powerful general-purpose technology that laid the groundwork for Schumpeterian transformations in production organization, product design, and business models and is recasting a significant portion of the economy [23]. The early phases of the ICT revolution principally affected services that are fundamentally about information: communications, finance, media, and insurance [54]. ATMs (automated teller machines) substituted for tellers in the existing business model, and although 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 beginning to be overturned. The offshoring of service work to locations such as India was only possible because content was digitized [13]. When content in media, from music and video to books and newspapers, began to be converted into digital formats and easily distributed, traditional business models were upended. Importantly, in the early internet phase of the digital revolution, ICT-enabled services, as mentioned above, began to be increasingly extended to "everything," and the underlying business models often changed character. Examples abound, some well-known, others less discussed: airplane engines, and even truck tires, can be sold as services with charges related to usage. Finally, in 2017 the impact of online purchasing is only beginning to be felt in retail, as brick-and-mortar stores are closing at an astonishing rate [33]. This will likely have a positive effect on productivity but negative effect on employment.

The platform phase is the latest step in this unfolding story of the deployment of ICT technologies throughout the economy. For a moment, let us focus on platforms. Certainly, platforms, which are digital and multisided, provide new ways for users, who could not previously reach one another and thus could not previously form a market, to interact. The Internet of Things, the Internet of Everything, and the Industrial Internet amount to new ways for sensor-enabled objects to be controlled and interact through platforms. The platforms facilitate the aggregation and analysis of data with the intent to control systems and actions. We are entering a world that will be characterized by the interplay of algorithms and data. It will be a data analysis–based economy and society, where the observation and interpretation of our behavior and the optimization of our physical systems will be based upon computation [39].

The breadth and dimensions of the impacts of platforms, sensor-based systems, and data analytics are breathtaking. In the prosaic world of industry, Cisco, GE, IBM, Huawei, and Siemens, in both their publicity and business strategies, highlight industrial applications from energy management to pipelines to aircraft management. For example, GE states that its goal is to integrate

ICT and data to provide solutions across industries including manufacturing, aviation, transportation, power generation, health care, and energy. These firms expect digitization to transform society and the economy.

The provocative German discussion of "Industrie 4.0" envisions how data capture and analytics will reform and reorganize manufacturing and supply chains. The German competitive advantage in manufacturing rests with skilled labor and specialized small and medium-size companies [25]. The question the initial study "Industrie 4.0" poses for the ongoing debate in Germany and elsewhere is how to craft cyber-tools in a platform economy to support and sustain skill-based competitive advantage. Research on both manufacturing and supply chains indicate that basic production is primed for reformulation through platforms and other ICT innovations. The important point is that we are in the midst of a transformation, not at the end.

This is all very well, the skeptics such as Gordon say, but where is the concrete evidence that this round of innovation will reignite rapid productivity growth as in the period that ended in the 1970s? Many alternate explanations of the productivity slowdown are unrelated to technology as such. Our purpose here is not to review or evaluate the complex and rich literature on productivity. Rather, it is to suggest the debates that will result from the economic character of the digital transformation. Alternate explanations of that slowdown include the impact of the 2007–8 financial collapse as well as the diversion of resources from productive investment to financial speculation [34].

Crucially for this discussion, productivity is not simply a technical matter but, rather, a reorganization of communities and work that affects. The deployment of technology is as crucial to productivity as the technology itself. One line of argument is that the technology diffusion machine in the advanced countries has broken down. For example, a recent paper from the Organization for Economic Cooperation and Development (OECD), "The Future of Productivity," contends that the productivity frontier has been pushed outward, but the best practices are not being implemented broadly in the economy. The study finds that the leading 10 percent of global firms have had significant and steady productivity increases in the twenty-first century while the other 90 percent lag far behind [37]. The problem then becomes one of deployment and diffusion, of business practices and structural policy, not of the inherent possibilities of the technologies.

The OECD results regarding the gap between the frontier and the rest will be debated. The study, in any case, raises important questions about the role of ICT technology 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 has broken, is the reason resistance, overregulation, policy, or incapacity at the level of the firm? As Perez [41] and the Schumpeterians suggest it might be that productivity advances in jumps, as new paradigms of organization and innovative technologies combine to permit new plateaus—a conclusion that would counsel patience [24]. 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 from the obstacles in the era of steam or electricity? As the Luddites showed in their reaction to the self-acting mule, technology deployment and diffusion are rarely a simple or conflict-free process. The mechanization of agriculture in the US proceeded relatively more smoothly because jobs were plentiful in the mass production factories of the industrial Midwest that could absorb the labor released from agricultural employment. Growth in the twenty-first century will involve deep dislocations in already rich, well-organized societies, and this will involve politically difficult choices [14, 51]. Capturing the potential of the technology is more a political problem than a narrowly economic constraint. Therefore, dealing with it calls for policy and political action, rather than a descent into economic pessimism.

Some contend that winner-take-all tendencies in the digital economy are at fault [8]. Are the leading 10 percent of firms at the productivity frontier because they have dominant market positions unavailable to the other 90 percent [1]? Along different lines, outsourcing business services, such as janitorial or even secretarial and bookkeeping, might well keep high-productivity activity in core firms and low productivity in the supplier companies. If this were the case, then the whole system might not be any more productive.[1]

In sum, we are in the midst of the digital ICT revolution. The effects emanate from a small set of information-based sectors or leaders at the frontiers of effective deployment and will diffuse throughout services and industry. We can decide later whether the period from 1970 to 2000 brought as profound a change in our way of life and standard of living as did the years 1870 to 1970. It is clear that the impact on productivity will depend not just on the technical advances developed but on the capacity to deploy and diffuse those possibilities. It is almost certain that sustainable productivity increases will be a necessary, though likely insufficient condition for increasing employment and wages.

4. WILL WORK HAVE A FUTURE? JOBS IN THE DIGITAL ECONOMY

From the abstraction of productivity, let us turn to the concrete question of jobs and work. Who will work? What will they do? How might they be compensated? How will labor markets be organized? The "jobs" question is as hard to sort through as the question of productivity. In fact, the digital influence on jobs and work creates several different discussions. Two are most important: labor markets created and transformed by platforms and the impact of CIAutomation on the character and organization of work.

[1] A study by McGowan et al. [37] find that productivity growth at global frontier firms increased at an average annual rate of 3.5 percent in the manufacturing sector over the 2000s, compared to average growth of just .5 percent at non-frontier firms. Indeed, the study contends that the gap between frontier and laggard firms has grown.

4a. Platforms and Labor Markets

The current focus in discussions on the influence of digital platforms on labor markets has been mainly on the way in which work is organized and compensated. The emphasis has been matching and the belief that jobs are being converted in increasing numbers from stable work into "gig" employment. This understates and improperly frames the issue.

Platforms from eBay and Amazon to Uber and Upwork and even YouTube are mechanisms for discovery and matching: matching 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 would improve. The premise is that digitization has transformed employment relations between employers and workers (capital/labor). The policy concern here is that the move of work to platforms risks facilitating a redefinition of the core of the economy from employment relations to gig and contract relations [18, 48]. An argument is being waged over how much has really changed; for example, one study suggests that in June 2016 only .9 percent of adults in the US actively earned income in the "online platform economy" [16]. It is important to note that the analysis in this study did not include those earning income on YouTube or raising funding through Kickstarter or other such platforms. Are there more such market relationships or are such relationships merely more visible now that they are online, rather than signaling a real increase in temporary work?

The academic research about the transfer of work to digital platforms, and the accompanying transformation of once-stable employment to more precarious work—though the work is diverse and expanding rapidly, nearly always focuses upon a single firm or sector, whether taxis and Uber or encyclopedias and Wikipedia. The current fixation on Uber and Airbnb is understandable as they directly challenge two significant traditional industries: transportation and hotel accommodations. These two cases involve the conversion of consumer goods—cars and residences—into commercial goods and, in the process, affect existing labor relationships. We can extend the scope of consideration to, for example, YouTube, which affects the entertainment and self-help industries, or Amazon's book self-publishing business, which affects publishing and the app stores—each of which converts the labor market relationship to one in which creators "consign" their work to the platform. In both, we see yet another vector of industry reorganization and, with it, a labor process change. When considered in this way, the impact of digital multisided platforms is far greater than the narrow focus on Uber and Upwork, and even YouTube, suggests.

To evaluate the platform economy, it is necessary to project beyond the most evident applications and their effect on the workforce and consider the ecosystems that they organize.

4b. ICT and the Reconceptualization of Productive Activity

Any discussion of work and jobs must consider how production of goods and services themselves will be reorganized as ever more sophisticated ICT is introduced [53]. Even as attention is focused on factories, warehouses are being automated, and various tasks performed by professionals are being assigned to "smart" programs [45]. A wide debate is taking place in the popular, consulting, and academic press. One debate, particularly in the popular press, focuses on specific technologies, such as artificial intelligence (AI), robotics, and 3D printing. Another debate, best represented by the now almost-iconic German analysis "Industrie 4.0" [25], considers how governments, unions, and companies should respond to preserve their position as the very character of production changes. The German export economy, of course, rests on the manufacturing of both goods and equipment and related services, with its competitive advantage built on its skilled workforce and the capabilities of small and medium-size specialized firms.

A third debate focuses broadly on the consequences of automation. The implication of a significant portion of that academic and popular literature is that the current digital revolution will indeed generate a world of greater unemployment, more unskilled workers, and greater inequality [8]. Certainly, many studies highlight concerns about the destruction and devaluation of work and skills [5]. However, if we include studies from a number of elite consulting firms, the conclusions are less clear. The tone struck in these studies ranges from one of urgency—job tasks will be transformed soon by automation—to one of complacency—the displacement is at a scale compatible with ordinary structural change in the economy. Where they land on this continuum from urgency to complacency depends on their judgment regarding what can be automated and is economically feasible to automate, the data sources used for estimating the possible changes, and the time frame of the structural changes chosen for observation.

The outcomes, the consequences for work and skills, will turn heavily on how the new emerging digital tools, the tools of CIAutomation, are deployed. That highlights a core conclusion rooted in the history of technology that emerging technologies have several different potential trajectories. Moving the technology frontier outward opens up new possibilities, while ending previous ones [12]. Each set of possibilities has distinct implications for value creation and capture. The new frontier, though, does not entirely determine the structures and organizational forms in which a technology is deployed. If the goal is to reduce auto emissions, one can electrify the entire vehicle fleet and then decarbonize the resulting increase in electricity production by using a renewable energy process, thereby moving to an entirely new energy system. Alternatively, and more in keeping with what the history of technology transitions suggests [2, 22], one can introduce a transition technology as Japanese automakers did with the Toyota Prius and Honda Insight hybrids. Hybrid auto technology can lead to improvements in other technologies, such as batteries and electrical engines for automobiles, while remaining within the extant carbon energy system infrastructure and preparing for a transition.

In any technological transition, new approaches to production organization and, with it, new strategies for entrepreneurship and new skills requirements, are likely to emerge. For instance, consider that in the past few decades, the early phases of the digital revolution, production has been decomposed while being shuffled geographically and then redeployed and reconstituted in new forms. Production was distributed through cross-national networks, with design and new product conception in Silicon Valley and production dispersed across Asia [6, 27]. Production reorganization continues, with implications for the organization and location, the sequence of activities, and the needed mix of worker skills.

Today's model is one in which prototyping occurs in advanced countries but mass production often occurs offshore prior to market testing. This not only is expensive but also limits the ability to adapt to the market. A new model for organizing production and sequencing the movement from prototype to volume production is being explored at the Flex Invention Lab in high-cost San Francisco. In this alternative, in the Flex Invention Lab, for example, using common components in prototypes and full-volume production, permits rapid production and process revision in response to the market. If demand increases to a certain threshold, the entire production process can be transferred to a high-volume factory. Flexible low-volume but automated production, such as 3D printing, will require skilled workers with not only software and hardware skills but also product integration experience.

Rather than centralized factories or decentralized individual customization, new approaches to production organization and, with it, new strategies for entrepreneurship and new skills requirements may emerge. It is possible that in the twenty-first century, no single dominant production system will emerge but, rather, a variety of ways for organizing productive activities as work is continually reconstituted and value chains are reconfigured. Mirroring what might become a plethora of organization models, it is possible for a wide variety of employment arrangements to result.

That leads us again to the question of the impact of CIAutomation on the tasks and work that people perform. Focusing solely on the jobs that may be displaced or transformed by CIAutomation hides the opportunities that will be revealed and the innovative possibilities that may be unleashed. Whether it is product designers for 3D printers in the maker movement or YouTube video creators, new work, new tasks, and new sources of income are being created. Moreover, the innovation dynamic itself has not been "automated" and remains a domain of human inventiveness and initiative—and, given online sources, capital for innovative activities appears to be more available than ever.

A crucial question, however, is whether this new world is going to be one with employment and reward for those who are not among the highly trained, upper 10 percent of individuals, those lucky enough to be anointed as YouTube "stars," have their app go viral, and start a new firm that is acquired by an existing firm or be employed at a core firm. Where will income come from for those with more modest training and education, who are not blessed by inherited status, not born with innate and recognized intelligence, or just not lucky? Some, such as Frey and Osborne, argued that broad categories of work that consist of standard routine tasks, arguably the bulk of current work, are directly vulnerable to displacement by CIAutomation [17]. In fact, this is not evident. Other research suggests that even routine manufacturing tasks, which seem most vulnerable to automation, are less routine than they may appear at first glance. Automation creates new shop-floor-level domains requiring judgment and augmented human capabilities [42].

An alternate view holds that computation can augment human intelligence and capacities. Indeed, some evidence indicates that even routine work can be augmented. Augmentation often has contradictory elements. In Japan, which suffers shortages of skilled heavy equipment operators, Komatsu introduced an excavator that uses computation to control the angle of the digging blade so that it uses the correct digging angle and does not dig too far. This enables equipment operators with lower skill levels to work effectively in situations in which, previously, only highly experienced operators could be used [3].

In any discussion of augmenting human capacities, user interfaces are critical. Essentially, programs, websites, and apps are user interfaces and thus augment and empower users while structuring capacities and activities. Some programs, such as Microsoft Word and Excel, used on personal computers led in part to the disappearance of secretaries and the emergence of staff assistants and computer specialists. The user interface powerfully influences who can use and deploy computing power.

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

Strategies for technology deployment are crucial. To illustrate, in the 1980s, as General Motors was threatened by Japanese competition, it began to implement automation to replace assembly-line workers. For dangerous and dirty tasks, such as painting automobile bodies, that was welcome. However, the GM strategy, which appeared to be motivated by the sole goal of replacing workers, proved ineffective, particularly when compared to the strategy employed by Toyota, which engaged its workforce in improving production, drawing on worker knowledge and insight, even while automating [49].

The choices made concerning the design, development, and deployment of the tools used for CIAutomation are crucial and lead to a very basic question: Are workers an asset to be promoted and developed? In that case, a primary challenge is imagining and investing in tools that make all workers more productive and effective—effectively a strategy for augmenting intelligence. For example, Zeynep Ton has shown that, even in the commodity retail business, a good jobs strategy of investment in workers and organizational strategies to engage worker possibilities and capabilities can be profitable [46].

The implication, stated simply, is that if society invests in technologies, business models, and companies in the belief that CIAutomation will inevitably displace work, if investment after investment is made to find ways of substituting capital for labor, then the result will inadvertently be a dystopian road to digital displacement. The prophecy of displacement of work because of ICT will be self-fulfilling. By contrast, if a concerted effort is made to discover how ICT can be used to augment intelligence and upgrade jobs throughout the spectrum of work, then perhaps these digital resources can be harnessed to build a broadly better future. Production in the twenty-first century will be reshaped through digital tools, in particular by CIAutomation, sensors, and data analytics [50]. So the question becomes "Is there a strategy for using computation to augment human intelligence?" For a discussion of work, what trajectory will CIAutomation, which underpins industrial reorganization and the design of work and labor markets, take? Will work be redesigned to leverage human cognition and creativity? Will robots and computation-intensive tools more generally simply displace workers? Or, is another direction a viable option? The outcomes lie in societal choices and visions for how technology is deployed and used; the outcomes are not inherent in the technology itself. The balance is yet to be determined, but it is likely easier to identify the specific situations in which CIAutomation that displaces jobs can be a good investment than to understand the ways in which worker-capacity augmentation can be advanced. It should be possible to design research initiatives to develop and elaborate a future that consider the impact on workers. If CIAutomation simply displaces work and lacks the retraining and creation of new employment opportunities, its continuing progress will create significant social challenges.

In sum, to understand the impact of ICT on work tasks and jobs, it is necessary to examine the reorganization of production and the transformation of work itself as well as labor market dynamics. If intelligence augmentation requires new skills or an integration of work in new ways, who invests in human skills and work redesign for an economy in which firm decision-making and work processes increasingly are predicated upon digital platforms driven by algorithms informed by machine learning?

5. POLICY AND POLITICS FOR THE PLATFORM ECONOMY

The sweeping changes brought about by digital technologies are initiating debates about the institutions and rules of the economy and society [36]. At the most fundamental level, they raise the question: How will the benefits of this promised new productivity be shared among the members of society? Will John Maynard Keynes's observation in 1930 that in the future a 15-hour work week could become the norm actually come to fruition [29]? The political question is, at its core, what sort of world is emerging as platforms and CIAutomation continue their progress?

The policy agenda is long and diverse, so a few comments to organize the discussion would be useful. As Nooren et al. [38] and others point out, in technological shifts as large as this one, a wide variety of sectors and regulatory issues is affected, but today the debates and discussions are siloed, despite the fact that decisions in one regulatory realm influence and affect developments and technological trajectories in other areas.

We propose thinking about the issue in terms of two categories of policies.

Platform Governance

The increasing power of the firms that own platforms raises the question of tension between private power and public governance. Far more than was the case with most previous industries, digital platforms are regulatory structures. Even more than was the case with natural monopolies, such as electrical power and water utilities, today's digital platforms deeply structure the rules and parameters of action for users. The classical statement in this regard was by Larry Lessig, who argued that governance was embedded in the software code itself [35]. In a somewhat different context, this was illustrated by Volkswagen, which embedded coding in its diesel-engine automobiles to circumvent emissions testing. At a larger level, firms can introduce platforms whose operations directly or indirectly circumvent existing regulations. As in the case of both Uber and Airbnb, the adoption of a new service can result in direct challenges to state regulatory authority. When the platform rules occupy an unregulated space or a space in which existing regulations are unclear and difficult to apply, then new platform businesses often compel consideration of new regulations or, at a minimum, new regulatory interpretations. To illustrate, should Airbnb landlords be subject to the land-use regulations and disability-access rules that apply to hotels? Moreover, platform-based private rule-making inscribed in software code creates rules that are not immediately evident for discussion and debate. And yet these platforms have remarkably powerful social impacts.

Managing the tensions between the public interest and private platform strategies requires that siloed and separated debates be integrated in policy discussions. In practice, questions about big data, privacy, and security are intimately connected. For example, as Stucke and Ezrachi point out, the new voice-activated digital helpers that Amazon and Google have introduced not only have privacy implications but also, because they recommend products and services, will affect competition [44]. Further, the introduction by both of these platform giants of payment systems may raise banking regulatory issues. Digital helpers are part of further vertical integration, which may result in antitrust issues. Decisions in one regulatory area can influence decisions in another field of regulation.

Most important is that the source of power for platform firms is their algorithms and the data they have collected. Not surprisingly, all these firms argue that their algorithms and data are trade secrets and should not be subject to government scrutiny – and their protestations do have merit. Finding a compromise will be difficult.

CIAutomation

To establish a technology trajectory within which CIAutomation contributes to human capacity, one objective must be to consider how harnessing computer-human complementarities can create advantage in the ways in which we will be valued and paid in the marketplace. An immediate research strategy seems evident. It is possible to begin research projects on how and why CIAutomation contributes to the augmentation of human capacities. Indeed, the required mix of skills will depend on how the ICT tools are deployed and on the user interfaces that are developed. From this research, it should be possible to infer the kinds of applications and deployments best suited to computer/human collaborations and then encourage their development and deployment. Identifying alternatives is difficult—recall that Japanese lean production strategies and the variants that have followed rest on engaging the workforce in continuous improvement. Moreover, the Japanese system proved to be very effective in manufacturing automobiles but far less effective in producing electronics and ineffective in creating software. It is so much easier for smart technologists to propose that they alone, to paraphrase rhetoric in the political debate, can develop and apply technology strategies. It is much harder to develop organizational strategies that involve the entire workforce, but perhaps we can learn from the maker movement in conceptualizing a different future.

Politics, of course, translates these debates into social and economic policy. Addressing the politics and economics of structural change caused by the increasing organization of social life and economic activity on platforms and the impact on employment and the work process as CIAutomation continues its advance is vital. In some sectors, coherent national responses will emerge, as is the case with Germany's "Industrie 4.0" initiative, while in others, such as the response to Amazon's domination in online retail, cogent national responses may be more difficult to attain. Indeed, politics will be an important shaping force for the character and scope of what are already discernable changes being brought about by the increased penetration of computation into economic and social life. Struggles that come with economic change will continue, as existing sectors decline or are transformed, as new firms displace old ones, and as existing workforces are pushed aside because of the creation of new forms of work and market organizations and rules. Struggles over governance are a certainty—between the public rules and the governance embedded in the "algorithms" and "coding" of the platform. Hopefully, this paper points the way and provides a framework for ongoing discussion.

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