Future of work

A Nokia Bell Labs perspective

White paper

This paper summarizes our perspectives on the future of work in the age of massive automation that will characterize the next industrial revolution. Although continuous improvements in technology and the constant drive to improve productivity have spurred increasing levels of automation since the First Industrial Revolution, there is a sense that an unprecedented jump in automation across all industries is around the corner. But the following factors make the current push toward higher productivity uniquely different from the past attempts: accelerating digitalization; a rise in cyber-physical technologies; rapid improvements in artificial intelligence and machine learning; and the impending arrival of high-performance 5G wireless suitable for industrial control applications. Whether this portends a dramatic transformation of work around the globe, with machines taking over human work at a massive scale, has been a topic of concern and debate in recent years. We build on the position set forth in Nokia's white paper "Preparing society for the Fourth Industrial Revolution" (Nokia, 2018) that these technologies will indeed transform work, and that the right strategies from businesses and judicious policies from regulators will result in net positive long-term impact on both the level of employment and quality of work. Our optimism is based on three premises: (1) a dramatic improvement in productivity due to new technologies raising living standards and demand; (2) a move toward fewer work hours enabled by automation; and (3) increasing emphasis on augmentation technologies that not only facilitate human-machine collaboration but also solve key skills and training challenges for workers in the new age.

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The automation future

Today, we are on the cusp of the next industrial revolution – one that promises to bring us closer to a virtually frictionless and constantly self-optimizing economy. This will be an era of unprecedented industrial automation enabled by a confluence of cyber-physical technologies and the emergence of smart digital network infrastructures.

The massive scale of automation will not just be transformational but also potentially highly disruptive to our lives, economies and governments. Understanding and managing the technological, economic and socio-political dimensions of this new wave of industrial transformation is imperative. The firms that get this right will be the winners in their respective industries, and countries that manage this well will lead the future global economy.

The most important domain of potential disruption from automation is the nature of work itself. In a pioneering study based on an analysis of 407 US professions published in 2013, Oxford University economists Carl Frey and Michael Osborne estimated that nearly 47% of US employment is at risk due to computerization and automation (Frey & Osborne, 2013). This work has spawned several studies by the World Bank, the US President's Council of Economic Advisers, the International Monetary Fund (IMF), and various consulting firms such as McKinsey, Accenture and Deloitte. These follow-on studies have refined the analysis by focusing on specific job tasks rather than occupations and extended it to other countries. They found the potential employment impact to be less than this level, but still substantial. Generally, the popular press has painted these studies as forewarnings of a jobless future. However, as Frey and Osborne clarified in an interview in 2018, these estimates are not predictions or the final words on the matter, but rather indications of how exposed today's work categories are to a rise in artificial intelligence and mobile robotics. They say nothing about the pace of automation, which is influenced by many factors, such as market forces that seek to maintain high demand for goods and services in the economy or socio-political ground realities. Neither do they rule out smart use of new technologies and holistic developmental policies that can shape the future of work.

We claim that the automation potential of new technologies will be fully realized while meeting the desired goal of **full, fulfilling and fully flexible** employment by harnessing three forces. Full employment is the natural outcome of the above-normal rise in productivity, which will raise aggregate demand by driving production costs lower and wages higher. Fulfilling employment will be achieved by a policy-guided timely reduction in hours worked per worker to exploit the jump in productivity and sustain high employment levels. Full flexibility will be enabled by the wide-scale adoption of "augmentation technologies" enabling increasing human–machine collaboration that will make the labor market highly fluid by supporting facile and continuous re-training of the future workforce.

The hyper-productivity future

"Productivity isn't everything, but, in the long run, it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker."
– Paul Krugman (Krugman, 1997)

Economists widely agree with this assertion. We have addressed the topic of the "productivity paradox" – sluggish growth in productivity despite rapid technological advances in recent decades – in companion publications (Kamat, Prakash, Saniee, & Weldon, 2019) (Saniee, Kamat, Prakash, & Weldon, 2017). Here we address the connection between productivity, automation and employment.

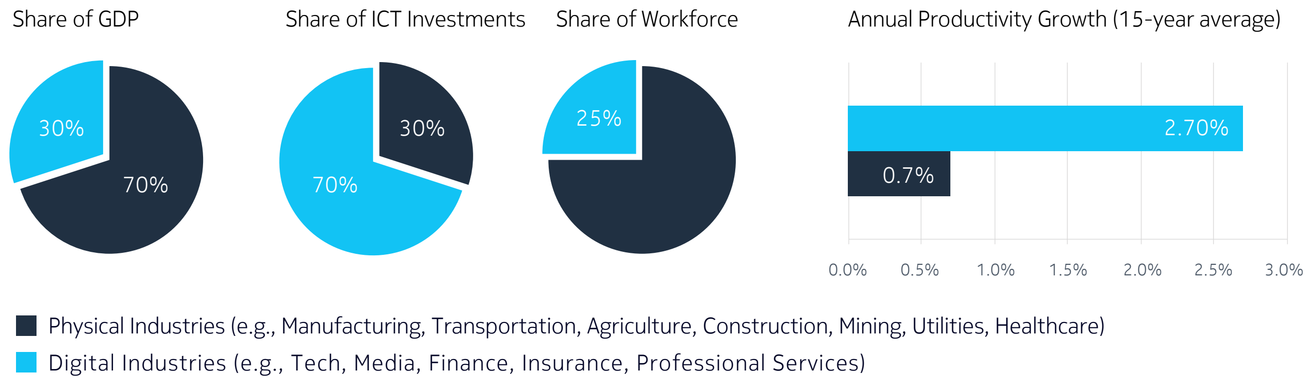
When productivity (i.e., output per hour worked) increases, we expect the production costs to drop, leading to lower prices, increased profits and consequently higher wages – all of which lead to higher disposable incomes and increased demand in the economy. This has the obvious potential to, in turn, create higher employment in a virtuous cycle. Michael Mandel and Bret Swanson (Mandel & Swanson, 2017) highlight the productivity dichotomy between physical and digital sectors of the US economy to illustrate this point. As seen in Figure 1, digital industries have dramatically outpaced physical industries in annual productivity growth. From 1996 to 2016, digital industries also grew their employment by 29%, while physical industries grew their employment by only 20%.

However, what if the rise in productivity that we project for these currently predominantly "physical" (manual, fixed configuration) industries comes from massive-scale automation of tasks that were previously done manually? There is a clear argument that when some tasks are automated, the increased productivity actually results in increased demand for labor to perform the other tasks that are not yet automated. Unforeseen new job categories will also be created. Yet the question remains whether the new jobs created from this increased demand will exceed the jobs lost to tasks that have become automated.

As analytically demonstrated by Daron Acemoglu and Pascual Restrepo (Acemoglu & Restrepo, 2018), we need to be primarily concerned about "so-so" automation technologies that only marginally improve the productivity of tasks when they are automated compared to their manual execution. Such automation is just marginally more productive and tips the scale in favor of machines displacing humans, but not significantly enough to lower prices and drive a significant increase in demand to create replacement jobs. When automation jumps to a much higher scale, the economics of production shift into a very different gear, as we have witnessed in some industries, such as semiconductors.

Clearly, we have evidence of orders-of-magnitude reductions in costs and prices of products and services created by digital industries over the years, driving up their demand. But we have not yet seen the same happen in the physical industries sector. As seen in Figure 1, the physical sector is the dominant contributor to total economic output (70% of GDP) and employment (75% of the workforce). While all industries look to automate tasks in pursuit of productivity improvement, we contend that the automation progress in the physical industries (such as manufacturing, healthcare, transportation, agriculture, mining, utilities and construction) in recent years has been in the "so-so" category, leading to weak employment and wage growth overall. We believe this is about to change for a number of reasons, as outlined below.

Figure 1 The productivity dichotomy in today's economy



(Data source: ref [Michael Mendel and Bret Swanson])

First, we need to acknowledge that automation is not automatic. Many conditions must be met before it is possible to automate a task. Automating an industrial task or process presumes: (1) a deep understanding of the dynamics of the process; (2) availability of technology to continuously monitor the current state of the process; and (3) the economic viability of collecting, analyzing and altering an optimal subset of the process parameters in time to shape its future state. These conditions have typically not been met for many industrial processes.

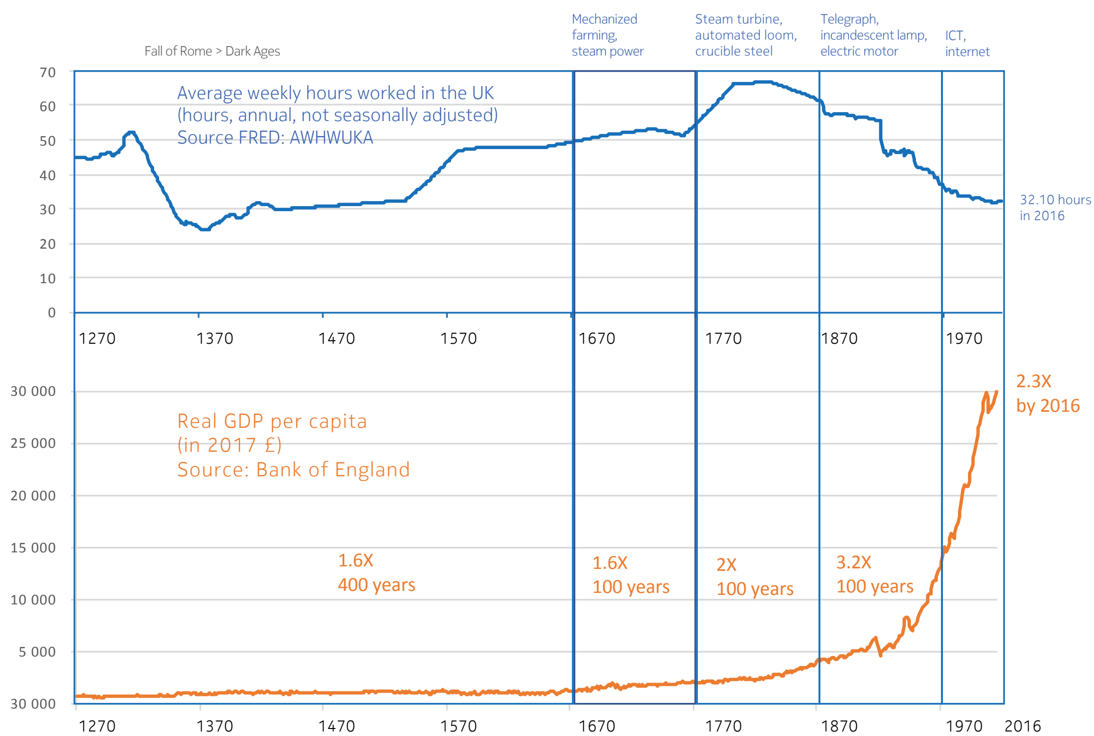
Digitalization is an important new catalyst for modern automation. Until recently, ICT applications were targeted to the digital industries (such as technology, media, finance, insurance and professional services), where digitalization was easy. Hence, the physical sector invested disproportionately less in ICT compared to its output and employment levels. Now, with the emergence of cyber-physical technologies such as mobile robotics and autonomous vehicles, 3D printing, augmented/virtual/mixed reality and Industrial IoT, physical industries' ICT investments and their pace of digitalization are starting to accelerate.

A new realm of automation capabilities will begin once digitalization and networking in physical industries cross a tipping point. Combining the cyber-physical technologies mentioned above with machine learning and high-capacity, low-latency, ultra-reliable wireless (5G) networking opens up a large space for industrial processes that can be intelligently automated. For jobs that require humans in the loop, AR capabilities that augment humans will make it easier for the workforce to transition from simple, repetitive physical tasks to more information-optimized, bespoke tasks and productive jobs that are required in this new economy. We have never before had the coincident combination of required technologies reaching the right level of maturity to enable industrial automation at scale. Now, for the first time in human history, we have the prospect of employing massive-scale automation across all physical systems and industries. This will make the dominant physical sector of the economy as productive, and its participants as prosperous, as those associated with the current digital one.

The fewer work hours future

While the hyper-productivity scenario described earlier should create a rising tide of demand, it may not equally lift all boats. How widely the benefits of productivity gains are shared and how sustained the productivity growth continues to be will depend not just on technology but also on how societies adapt to the new potential of these technologies. We live in times where technology changes much faster than social norms and work practices. When the promised dramatic rise in productivity arrives, adjusting the hours worked per worker downward can not only ensure high employment but also sustain productivity growth by incentivizing smart work practices.

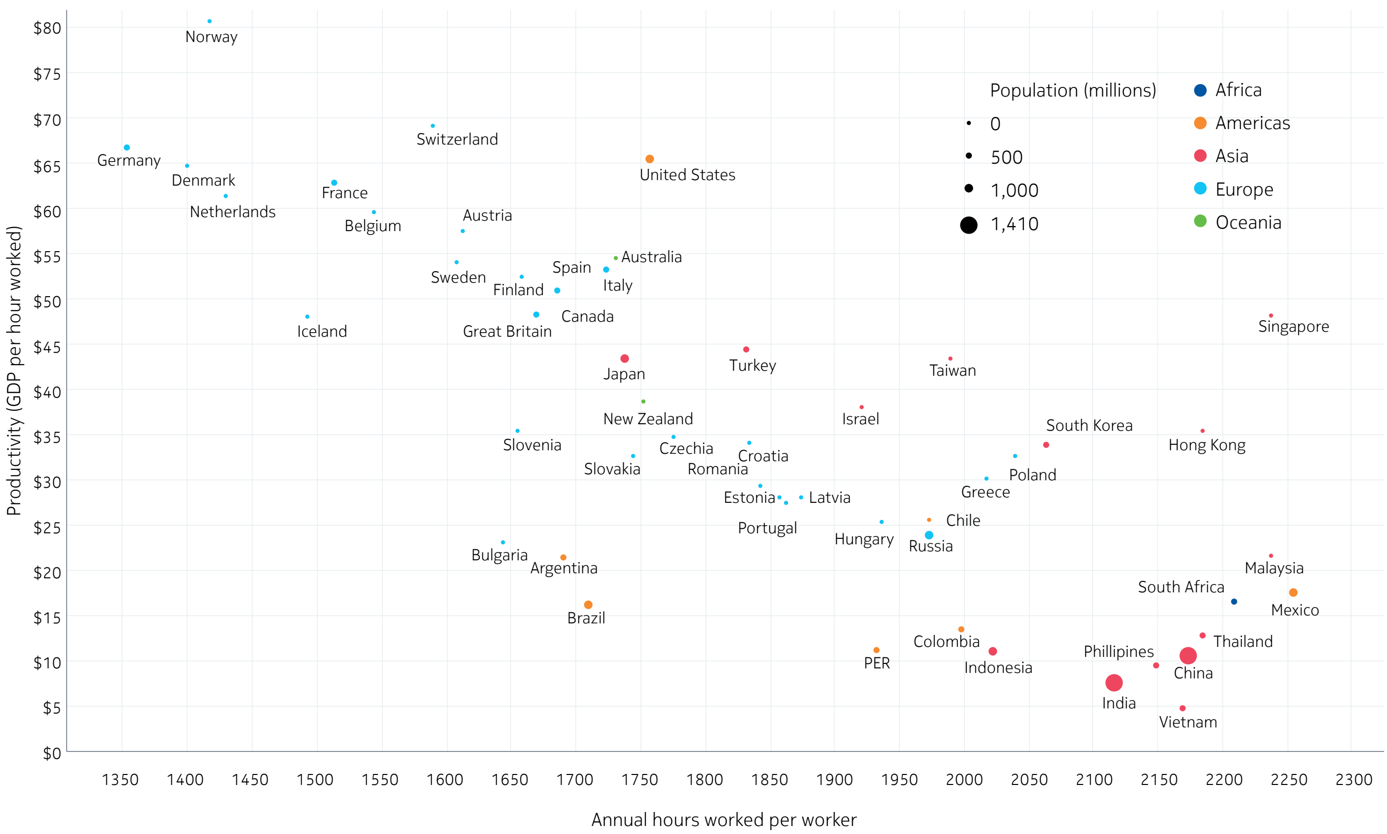
Figure 2 Hours worked and GDP per capita in England over seven centuries



(Data source: Bank of England and Federal Reserve Economic Data (FRED), Federal Reserve Bank of St. Louis)

As seen in Figure 2, the evolution toward shorter work weeks came about as industrialization progressed, often with protracted labor movements and hard-fought legislative battles to realize these changes. Today, we typically see long or short work hours reflect the cultural norms of different societies. However, as Figure 3 shows, there is actually an inverse correlation between productivity and hours worked across all economies. More productivity leads to increased incomes and to wealth that is then usually strongly correlated to shorter work hours, that leads directly to an increase in leisure hours. There is also growing evidence that a reduction in work hours itself drives higher productivity (McGregor, 2019) (Glaveski, 2018) (Collewet & Sauermann, 2017). There are a few aspects to this. In societies where long work hours have become the norm, policies that reward increased productivity through a combination of increased wages and reduced work hours will provide more capacity for leisure. Then companies that operate round the clock will hire more workers to compensate for reduced work hours per worker, keeping the employment level high. Increased automation of tedious tasks will put a premium on workers' creative and cognitive skills and capabilities, which also tend to improve with increased leisure time and constrained work hours. A combination of increased disposable income and leisure time plus lower prices, all enabled by the jump in productivity, will cumulatively ensure growth in demand for products and services in a positive feedback loop.

Figure 3 Annual hours worked vs. productivity



(Data source: Penn World Table, University of Groningen, Our World in Data, World Bank; bubble size proportional to country population)

The pervasive augmentation future

The skills gap is still a major challenge to overcome before employment can reach its full potential, even with high demand and availability of workers. Large sectors such as manufacturing, mining and utilities in advanced economies have seen a decline in employment over the past many decades that is not due to automation or outsourcing but difficulty in finding skilled workers.

The skills gap in the job market can only be fixed with training. But fewer people are receiving education aimed at employment in these traditional sectors. This challenge will worsen in the future as the emergence of new technologies and reconfiguration of workflows will create new job categories demanding new skills. The education sector is not currently geared to address this challenge.

Under these conditions, the burden of training workers for dynamically evolving jobs and making them productive will largely fall on employers. Fortunately, this problem can be addressed in part by the increasing use of augmentation technologies, where machines and human–machine interfaces are explicitly designed with the goal of augmenting humans with skills, knowledge and intelligence to perform new tasks. In many instances, augmented intelligence (AugI) will remove the requirement for workers to be pre-trained with domain-specific knowledge needed for a job or task. A worker passing benchmark tests in dexterity and cognitive skills will more easily move across a wide range of jobs within an industrial or service organization, using AugI tools and devices such as headsets and goggles, employing common sense (e.g., do not touch live wire that is showing as red in AR goggles) and by being able to improve their performance from the feedback given by these AugI tools.

Figure 4 Conventional worker of today vs. augmented worker of tomorrow. Source: Bell Labs Consulting

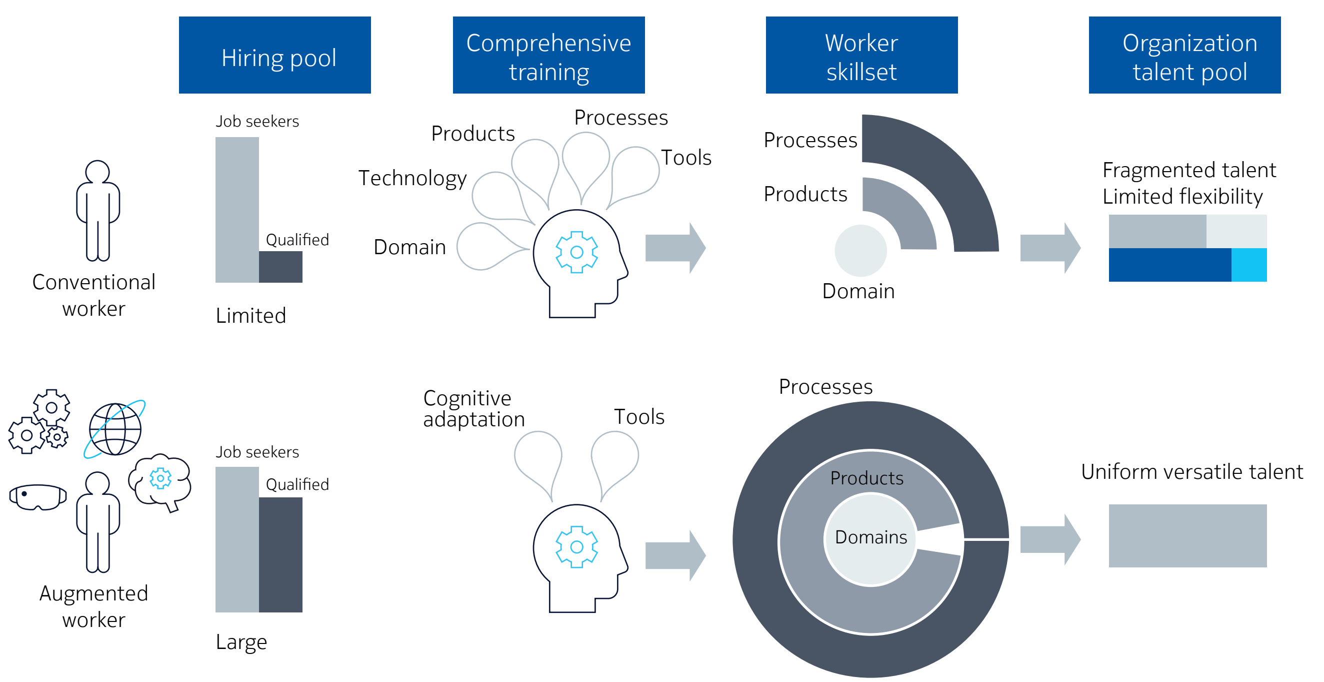


Figure 4 summarizes our view of the differences between a conventional worker of today and a typical augmented worker of tomorrow, and how these differences will impact work and the labor market. Today, employers have to expend significant resources sifting through a large number of jobseekers to identify a small subset of qualified candidates. The selected workers then have to be trained comprehensively in all relevant work domains, technologies, products, processes and tools. This, in the end, creates specialists who, with experience, become highly productive in performing a specialized set of tasks, limiting the employer's flexibility to reassign them to new tasks that may be needed. But in the future AugI world, all products, processes and tools will be designed for human augmentation. This means employers will be able to lower the bar set by prior specialized skills or education when hiring and instead focus on the candidate's drive and capability to learn new skills and technologies. This will create a highly versatile worker pool and make the labor market more fluid. Simultaneously, it will also reward ongoing learning among workers, making their work both more interesting and productive.

Just as lesser-skilled workers will extend their capabilities by augmenting themselves with machines, expert humans will also extend the capabilities of machines designed to learn and enhance AugI tools and systems, making the benefits widespread across the employment spectrum. While the popular press often focusses on the capabilities of new AI technologies to replace humans, there are many critical cognitive and bespoke physical tasks where humans are superior to machines, and human–machine collaboration will enrich the future work environment in unimaginable ways.

Conclusion

Fuller-employment and fulfilling work future with full flexibility

The future of work promises to be full of surprises. Even with unprecedented levels of automation across all industries, a combination of the dramatic increase in productivity, shorter work hours and human-machine augmentation comes with the potential for fuller employment and more fulfilling work with full flexibility to adapt to any and all changes that will occur in this vastly shifting employment landscape.

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Abbreviations

AI	artificial Intelligence
AR	augmented reality
AugI	augmented intelligence
ICT	information communications technology
IoT	Internet of things

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